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Wabash Oil Co.
No. 1.

Coalinga Field,
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BULLETIN No. 32. SAN FRANCISCO, MARCH, 1904.

PRODUCTION AND USE

OF

PETROLEUM IN CALIFORNIA.

ISSUED BY

CALIFORNIA STATE MINING BUREAU,

FERRY BUILDING, SAN FRANCISCO.

LEWIS E. AUBURY - - State Mineralogist.

SACRAMENTO.
W. W. SHANNON - - - SUPERINTENDENT STATE PRINTING.
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LETTER OF TRANSMITTAL.

To HON. GEORGE C. PARDEE, *Governor of the State of California, and the Honorable Board of Trustees of the State Mining Bureau:*

GENTLEMEN: I have the honor to transmit to you Bulletin No. 32, entitled "Production and Use of Petroleum in California." This bulletin has been prepared by Mr. Paul W. Prutzman, Engineering Chemist, of this city, from his own observations and from data and photographs furnished by Field Assistants of the State Mining Bureau; also from authorities to whom credit is given in the following pages.

The work on the bulletin has extended over a period of two years, and the greatest care has been exercised in the collection of accurate data concerning the subject treated. It was completed and the manuscript handed to me in March of this year, but it has taken some time to prepare engravings, maps, etc., and to have the bulletin printed. The aim of the bulletin is to describe the conditions under which petroleum is produced, the amount, source, and character of production of same, and to outline some of the more important ways in which the output is consumed. As the subject has been one of considerable detail, it has been necessary to condense the matter as far as possible.

Bulletin No. 31, of this department, has been inserted in this publication. This data concerning authentic samples of oil, collected by a Field Assistant of the Bureau, with analyses of the same made by Mr. H. N. Cooper, has been embodied in Bulletin No. 32 in order that the information, which is considered of value to those interested in the oil industry, might be at hand with other data concerning the subject.

The bulletin has been prepared with a view of submitting to the general public a knowledge of conditions existing in the oil industry at the present time. As in other bulletins prepared under my direction, endeavor has been made to avoid technicalities wherever possible, in the hope of making the bulletin plain and readable to all interested in petroleum and its uses in this State.

Thanks are due and are cordially extended to all those who have aided Mr. Prutzman in the preparation of this bulletin.

Respectfully submitted.

LEWIS E. AUBURY,
State Mineralogist.

SAN FRANCISCO, June 30, 1904.

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PRODUCTION AND USE OF PETROLEUM IN CALIFORNIA.

By PAUL W. PRUTZMAN,
Engineering Chemist.

PART I. PRODUCTION.

CHAPTER 1.

HISTORY AND PRODUCTION.

History.—The existence of asphaltum and petroleum in California was familiar to the first settlers in the State, and semi-solid bitumen from seepages in the southern portion of the State was used, from very early times, as fuel and as a cement. As early as 1856 the more liquid petroleum from several seepages was collected and refined in a crude way, burning and lubricating oils being made. At least one of these refineries was quite an extensive affair, but none of them seem to have been successful financially, and all were soon abandoned, although a number of asphalt refining plants, established at about the same time, were longer lived. The earliest of these refineries antedated the first production of oil from wells by at least eight years, a rather remarkable reversal of the usual order.[1]

The oil industry of California actually dates back to 1865, when Prof. Benjamin Silliman was called on, by parties having interests in Ventura County, to collect and examine samples of petroleum from seepages in that district. His report was so glowing in its praises of the oils obtained, and the times were so propitious (being contemporary with the oil excitement in Pennsylvania), that immense enthusiasm was created among the speculatively inclined, and developments were undertaken in almost all parts of the State. Wells were drilled in Humboldt, Mendocino, Santa Clara, Santa Cruz, Contra Costa, Colusa, Santa Barbara, Ventura, and possibly in other counties, but no actual production was obtained outside of Ventura County. Drilling proved to be very difficult, so that a large number of holes were spoiled; it soon appeared that Prof. Silliman had been grossly imposed on in the matter of samples, the oil actually obtained being of far different quality from that which he examined, and the boom proved a fleeting one. Some producing wells were, however, obtained in the shallow formations of Ventura County, and from this nucleus gradually but slowly grew an industry of considerable local importance.

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[1] For full information as to these early operations consult Reports of the State Mineralogist of California, years 1894 and 1897.

From this time on, very little development work was done until, in 1892, E. S. Doheny drilled by hand a shallow well near some asphaltum deposits in the city of Los Angeles, and obtained a small but steady production of heavy black oil. The interest caused by this discovery not only brought about the drilling of several hundred wells in the vicinity, most of which were and still are productive, but renewed interest also in the outlying fields. Again prospecting was undertaken at many points, and again with practically no results for the time. But it had been demonstrated that oil existed beyond the bounds of Ventura County, and the work of the wildcatter was now carried forward with much more vigor, and with immensely better chances of success. In 1895, C. A. Canfield and others took over a property in Fresno County, near the little village of Coalinga, where other Los Angeles parties had been drilling without results, and after much effort finally brought in a small well, which produced the lightest oil found in the State up to that time. Some little interest was aroused, and several companies based on local capital started to drill in or near the section where Mr. Canfield was still working, and in 1896, after a number of small wells had been finished, the Home Oil Company of Selma brought in the famous "Blue Goose," a flowing well of very respectable proportions.

The boom which followed this discovery was unrivaled in the history of the State, for hardly had the interest in this discovery, and in the large wells which followed it, subsided, than oil was discovered on the James Means ranch near Bakersfield. Within three years some two thousand four hundred oil companies filed incorporation papers in this State; most of this number sold more or less stock, while at least twelve hundred companies did some actual drilling. Again the State was punctured from one end to the other, but this time with much more success, for while the northern counties again failed to fulfill expectations, the operators in Kern River, Coalinga, Sunset, Midway, McKittrick, Whittier, and Fullerton were more fortunate.

The boom went the way of all booms. Great numbers of companies were promoted by unprincipled parties, who put the proceeds of stock sales out of harm's way; many more were so mismanaged as to waste their entire resources on preparations, while others were unfortunate in their locations. The production of the Kern River field for the first year was several times the entire production of the State for any year previous, and as a consequence the price of oil, which had ranged from $1 to $1.50 per barrel, fell to eight or ten cents, producing companies could not pay running expenses, stock sales ceased, and the bubble collapsed.

But the boom, while disastrous to many individuals, was of much real benefit to the oil industry and to the State at large. Hundreds of companies located in the most remote and unlikely spots, where legitimate capital would probably never have been risked, and while the percentage of failures was of course very large, yet the wildcatters did develop several hundred wells in entirely new territory, thus proving up ground which would otherwise have remained untouched, and when the excitement had passed away the production of the State had increased from two and one-half million to nearly seven and three-fourths million barrels per annum, an enormous amount of well-invested capital remained in the business, and it had been shown that, under rational management, the production of and even the prospecting for petroleum in California formed legitimate employment for capital.

Production.—The present production of petroleum in this State is purely and simply a matter of possible consumption. The potential possibilities of increase of production is hardly a matter for figures. The fields mentioned farther on as producing fields include, as may readily be seen on examination of the accompanying maps, several hundred square miles of territory which, while not all definitely proven up, is highly probable to prove profitable ground. And further, of all the forty or so square miles of actually producing territory in the State, there is probably not one square mile, outside of Los Angeles, Summerland, and some parts of Ventura County, which has been drilled to anything like its maximum capacity. This is not the place to go into details as to possible production, but it will probably be admitted without argument, by most persons familiar with the situation, that the present production could be increased, did the consumption warrant, by at least three or four times, within the time required to sink the necessary wells.

In the year 1901 the production of petroleum for the entire world was 165,350,000 barrels (Mineral Resources, 1901, U. S. Geol. Survey), of which the United States produced 69,350,000, or 41.97%. In this year California produced about 7,750,000 barrels, equal to 12.7% of the production of the United States, or 5.33% of the production of the entire world.

In 1902, the total mineral production of California was valued at $35,000,000. The product of first importance was gold, valued at $16,900,000; petroleum was second, with $5,200,000; and structural materials third, with $4,100,000. The comparison of these figures does not, however, give petroleum its proper place as to importance to the prosperity of the State. The sums realized from manufacturing industries made possible to the State by the large output of cheap fuel oil are not subject to calculation, but must be very large. It would be difficult to overestimate the impetus given to local industry by the cheapening of fuel during the last two years. At present prices, petroleum for steam generation costs in San Francisco a very little more than the equivalent quantity of coal would cost in New York city. When it is remembered that for years coal of a rather inferior quality sold in cargo lots at this port at from $4.00 to $5.50 per ton, it will be seen that the reduction in fuel costs has been enormous.

The following table shows the quantity of petroleum produced in California from 1898 to 1902, inclusive; the estimated value; the percentage of the total production of the United States as to quantity and as to value; and the rank of California among the American states, as to quantity produced and as to value of the product:

TABLE 1. Quantity of Petroleum Produced in California from 1898 to 1902, inclusive; Estimated Value; Percentage of Total Production of United States, and Rank of California among American States.

YEAR.	PRODUCTION.		PERCENTAGE.		RANK.	
	Barrels.	Value.	Quantity.	Value.	Quantity.	Value.
1898	2,249,088	$2,376,420	4.06%	....	5th	....
1899	2,677,875	2,660,793	4.60	....	5th	....
1900	4,329,950	4,152,928	6.76	5.38%	5th	5th
1901	7,710,315	2,961,122	12.70	4.46	4th	5th
1902	14,356,910	4,692,189	16.44	....	4th	....

Table 2, following, shows the production by counties for the same years, in barrels, in value, and in percentages of the State's production as to quantity and value:

TABLE 2. PRODUCTION BY COUNTIES, 1897 TO 1902.

COUNTY.	1897.				1898.			
	Barrels.		Value.		Barrels.		Value.	
Fresno	70,140	3.6%	$70,840	3.7%	154,000	6.8%	$154,000	6.5%
Kern	....	....	....	....	10,000	0.5	10,000	0.4
Los Angeles	1,327,011	69.5	1,327,011	69.3	1,462,871	65.0	1,462,871	61.6
Orange	12,000	0.6	12,000	0.6	60,000	2.7	60,000	2.5
Santa Barbara	130,136	6.8	130,136	6.7	132,217	5.9	112,549	4.7
Santa Clara	4,000	0.2	10,000	0.5	3,000	0.1	6,000	0.3
Ventura	368,282	19.3	368,282	19.2	427,000	19.0	571,000	24.0
	1,911,569	......	$1,918,269	......	2,249,088	......	$2,376,420	......

TABLE 2. PRODUCTION BY COUNTIES, 1897 TO 1902—Continued.

COUNTY.	1899.				1900.			
	Barrels.		Value.		Barrels.		Value.	
Fresno	439,372	16.5%	$439,372	16.5%	547,960	12.6%	$547,960	13.2%
Kern	15,000	0.6	13,500	0.5	919,275	21.3	827,848	19.9
Los Angeles	1,409,356	52.7	1,409,356	53.0	1,722,887	39.9	1,722,887	41.5
Orange	108,077	4.0	108,077	4.1	254,397	5.9	254,397	6.1
Santa Barbara	208,370	7.9	191,288	7.2	183,498	4.3	165,138	4.0
Santa Clara	1,500	0.1	3,000	0.1	......	......	......	......
Ventura	496,200	18.2	496,200	18.6	443,000	10.3	398,700	9.6
Unapportioned	......	......	......	......	248,945	5.7	236,498	5.7
	2,677,875	......	$2,660,793	......	4,319,950	......	4,152,928	......
	1901.				1902.			
Fresno	525,453	6.8%	$236,444	8.0%	571,258	4.0%	$199,931	4.2%
Kern	3,902,125	50.7	1,131,616	38.2	9,777,948	68.0	1,965,585	41.7
Los Angeles	2,304,432	29.9	1,062,058	36.0	2,196,406	15.4	1,075,868	22.9
Orange	302,632	3.9	181,501	6.1	1,108,793	7.7	824,492	17.6
Santa Barbara	205,616	2.6	113,385	3.7	230,440	1.6	181,313	3.9
Ventura	472,057	6.1	236,028	8.0	475,000	3.3	455,000	9.7
	7,710,315	......	$2,961,102	......	14,356,910	......	$4,692,189	......

CHAPTER 2.

TOPOGRAPHY: GEOLOGY: DRILLING.[1]

Topography and Climate.—The State of California, covering an area of about 156,000 square miles, and extending over ten degrees each of latitude and longitude, embraces within its bounds all the variations of topography and climate known to the temperate zone. With the mountainous forest region to the north, the territory of the Sierra Nevada on the east, and the alkaline desert east of the mountains, this article has no connection, and they may be passed without comment. The oil deposits of the State have been confined to the central valley and to the

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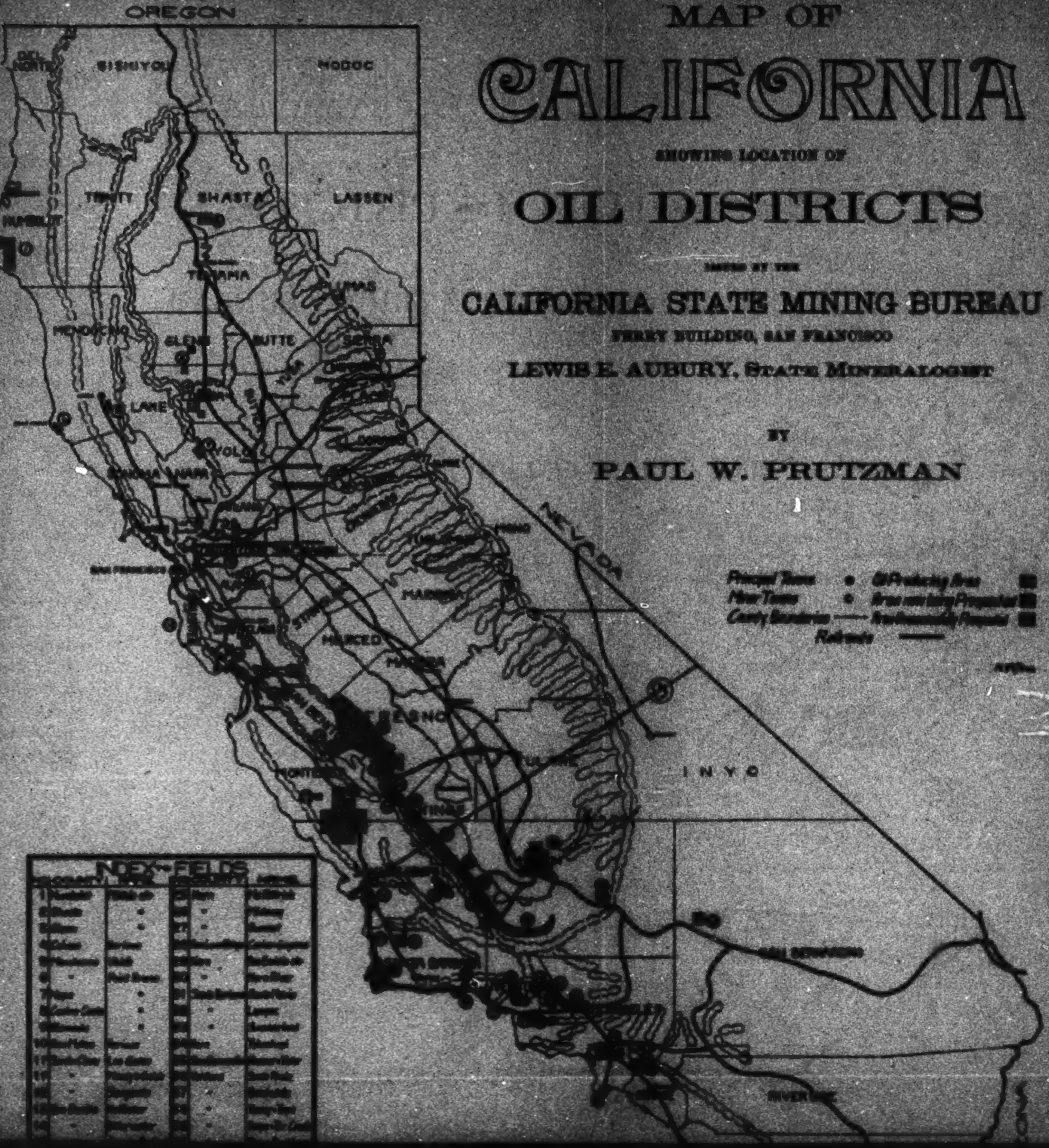
[1] Reproduced from a paper by the writer in "Petroleum Review and Mining News" (London), October 24, 1903.

Coast Range, and of these districts both climate and topography merit a brief description.

The magnificent Sierra Nevada range, which in general height about equals the Alps, slopes gradually down to the valleys of the San Joaquin and Sacramento rivers, lying in the center of the State, and paralleling its length for some four hundred miles. These rivers flow from north and south toward the center of the State, where they bend to the west, and enter the Pacific Ocean, through San Pablo Bay, at San Francisco. The two valleys thus formed have an average breadth of about forty miles, with a soil of exceeding fertility. The summer climate is hot and rainless, that of winter mild, with moderate rains. Between these valleys and the ocean, and roughly parallel with each other and with the coast, lie a number of ranges of low mountains, which together form the Coast Range, rising sometimes to a height of 2000 feet. The eastern side of these mountains is generally barren, but as the coast is approached the fertility increases and the climate becomes more equable, until along the coast proper the difference between summer and winter can hardly be noticed, except for the absence of rain during the former season. The soil of these hills is usually of clay and shale, very little rock, comparatively, being on the surface. Between these hill ranges lie many small valleys, resembling the central valley in soil and climate.

The producing oil fields are found at the southern end of the central valley and along its southwestern slope, and on the ocean side of the Coast Range in its southerly part. Prospecting has been carried on in the central valley as far north as Shasta County, and on the ocean slope of the Coast Range almost to the northern boundary of the State. These fields are located with approximate correctness in the accompanying map (Fig. 1), which will also give an idea as to transportation facilities. It should be noted that the fields not contiguous to the coast depend entirely on the railroads, the rivers not being navigable, and that the Tehachapi Mountains in southern Kern County form a natural division to the State, on account of heavy grades and consequent high freights. It will be seen that the territory north of these mountains is tributary to San Francisco, as this is the only point at which the Coast Range is enough broken to allow easy access to the ocean, and south of these mountains to Los Angeles. The refining oil of Santa Barbara, Ventura, and Los Angeles counties finds its way to San Francisco by water, and to Los Angeles by rail; the heavy oil goes to Los Angeles.

Geology.—The geological structure of the State is simple in theory, though complicated enough in detail. The granitic core of the Sierra Nevada forms the backbone of the State, and carries on its flanks narrow exposures of pre-Cretaceous strata running back as far as Devonian, usually much altered, and overlaid on the west by the Pleistocene formations of the central valley. West of the valley the Coast Range shows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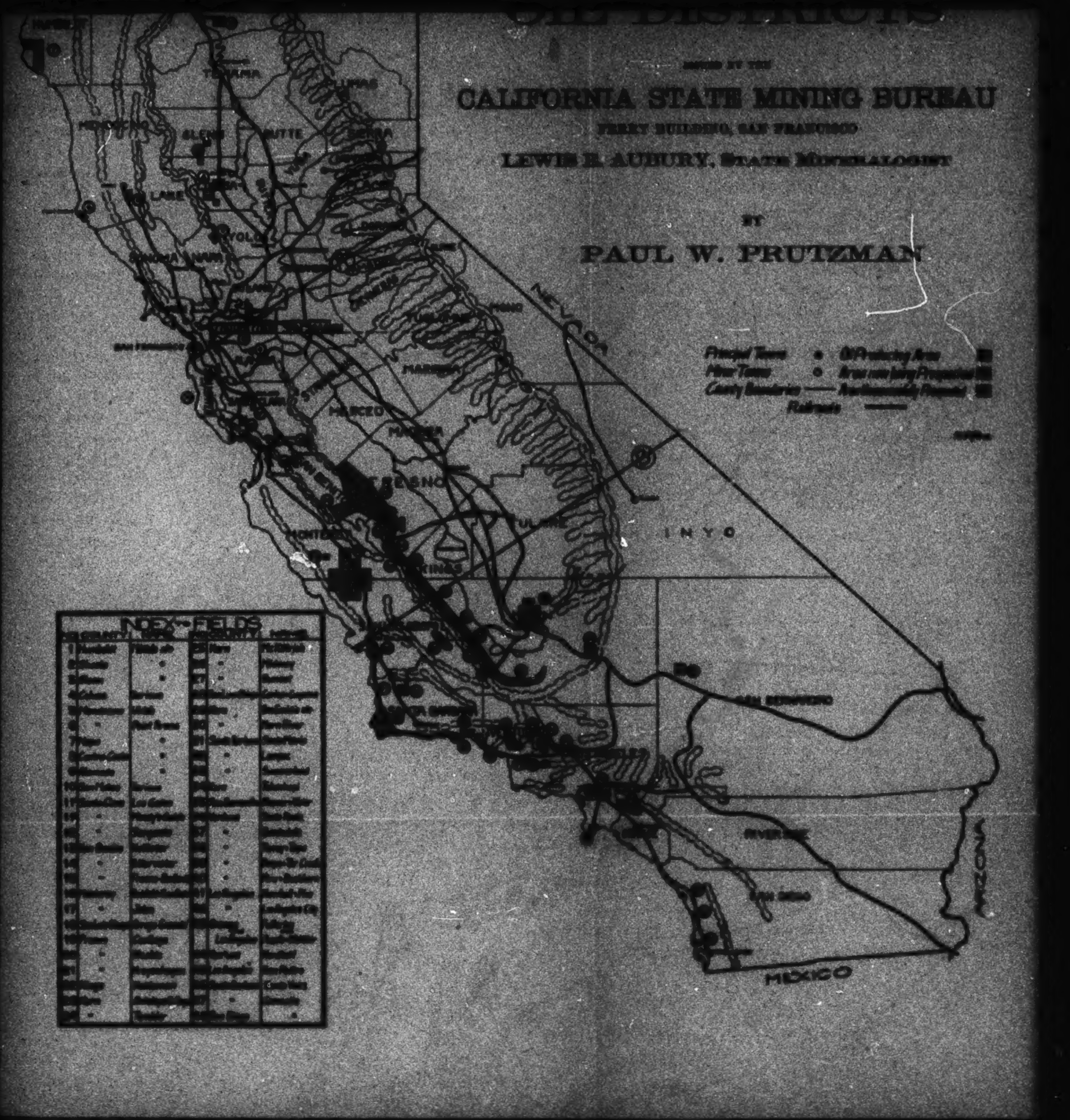
SIERRA
LAKE
YOLO
SONOMA
NAPA
SAN FRANCISCO
NEVADA
MARIPOSA
MERCED
MADERA
FRESNO
MONTEREY
TULARE
KINGS
INYO
SAN BERNARDINO
RIVERSIDE
Principal Towns ●
Minor Towns ○
County Boundaries ——
Oil Producing Area ■
Area now being Prospected ■
Area Unsuccessfully Prospected ■
Railroads ——
INDEX TO FIELDS

MAP OF
CALIFORNIA
SHOWING LOCATION OF
OIL DISTRICTS
ISSUED BY THE
CALIFORNIA STATE MINING BUREAU
FERRY BUILDING, SAN FRANCISCO
LEWIS E. AUBURY, STATE MINERALOGIST

BY

PAUL W. PRUTZMAN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OIL DISTRICTS

ISSUED BY THE

CALIFORNIA STATE MINING BUREAU

FERRY BUILDING, SAN FRANCISCO

LEWIS E. AUBURY, STATE MINERALOGIST

BY

PAUL W. PRUTZMAN

generally a core of igneous rock, overlaid on both sides by Cretaceous and later formations. As the oil deposits in the central part of the State are principally found near the foot of the Coast Range, wells here penetrate formations of Eocene to Pleistocene age, largely shales, clays, and sandstones. The oil wells of Ventura County are partly located in a base limestone of Eocene age, partly in shales of a somewhat later period. The Oil City pool of Coalinga is in the Tejon (Cretaceous), some practically unproductive wells in Colusa County are in Cretaceous formation, and the Newhall field of Los Angeles is at the edge of a granitic intrusion. With these exceptions our oil production is from strata of Miocene and Pliocene age.

The accompanying sections (Fig. 2), due to the kindness of Dr. Harold W. Fairbanks, of Berkeley, Cal., show in a generalized manner the order of formation across the State, on two lines noted on Fig. 1.

Difficulties of Drilling.—The exposed formations in those parts of the State where oil is found being, as stated, of very recent formation, it is but natural that they should be soft. There are small areas of regional metamorphism and a few exposures of eruptive rock, the latter being, as a rule, decomposed to soft serpentine, but neither metamorphic nor eruptive areas touch the oil

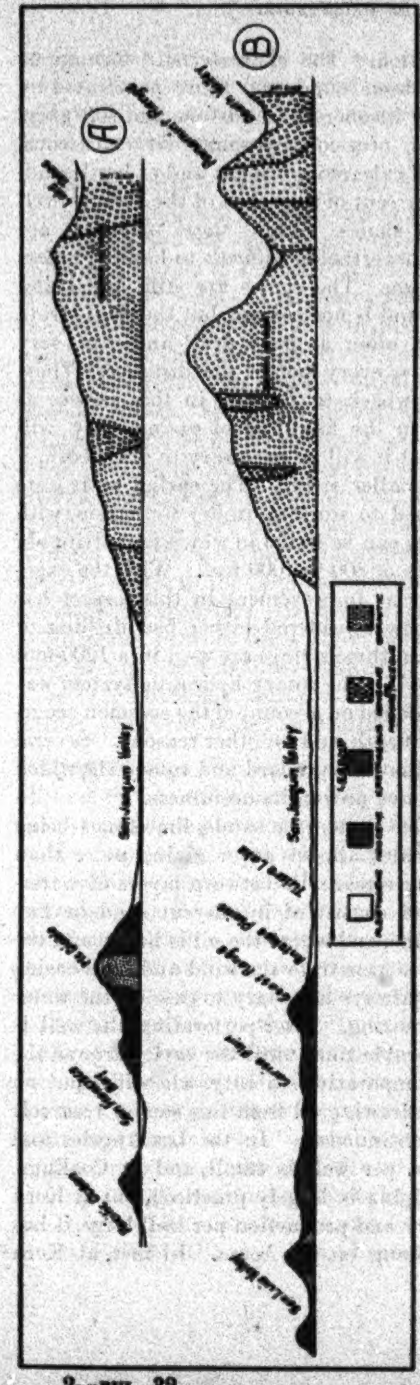


FIG. 2. Geological Sections across California. (Courtesy of Dr. Harold W. Fairbanks.)

fields directly, with one exception. The characteristic formations exposed at points where oil has been found, and those penetrated by drilling, are of soft, often entirely incoherent, sandstone and soft gray, blue and black shales and clays, occasionally somewhat calcareous. There are also scattering layers of calcareous cement and of hard sandstone, but probably ninety-five per cent of the depth of the average well is through loose sands and soft shales. While these materials are readily drilled through, they are nevertheless difficult to handle, unless precaution be taken against caving. The shales are stiff, and stand up reasonably well where the ground is not too wet, but the sand strata almost always carry some water, often a great deal, and run very badly, so that it is necessary to case every foot of the distance. These running sands are the great drawback to drilling in this region, as with the slightest carelessness in the handling of casing, they will freeze two strings together, so that it will be necessary to draw both, if that be possible, or to insert a smaller string. The earlier wells were drilled largely by men accustomed to working in dry formation, with the result that some of these holes can be found in which four strings of casing were used to reach a depth of 800 to 1000 feet. With the experience of the last three years a great improvement in this respect has been brought about, and it is now considered either bad drilling or exceptionally bad luck if more than three strings are used in a 1200-foot hole, while often only two are used. The rotary hydraulic system was rather extensively tried, but abandoned on account of the common occurrence of bowlders at considerable depth, and for other reasons. Several operators are now trying a combination standard and rotary rig, which promises well, but is too new to have proven its usefulness.

The oil sands proper are, in this State, true sands, limestones being practically unknown, and the shales almost never giving more than seepages. In general, the paying streaks lie between layers of water-saturated blue or gray clay, and consist of incoherent sand or fine gravel. Often the sand is very fine, and where the oil is heavy and the gas pressure high, it is difficult to penetrate the sand and land casing in the clay below. It is almost always necessary to case off the water above the oil sand with a larger string. After perforating, the well is sand-pumped, often for a considerable time, until the cavity around the perforations reaches a state of comparative stability, when it is put on the pump. But almost all wells drawing oil from this sort of reservoir will pump more or less sand continuously. In the Los Angeles and Ventura fields, where production per well is small, and at Coalinga, where the oil is light, jack pumping is largely practiced, but at Kern and Sunset, where the oil is heavy and production per well large, it has been found better practice to pump on the beam. In fact, at Kern

River, where the sand is fine and runs badly, choking of perforations makes it necessary to clean often, and almost enforces leaving a rig at each well. It seems hardly necessary to state that wells in this soft formation are never shot.

Cost of Wells.—Data are not at hand from which to state definitely the cost of completing a well, except in the Kern River field; in fact, at no other point are conditions uniform enough to allow one figure to apply to all parts of a field. In this district the average depth is about 1000 feet, and wells can be contracted, including casing, at about $3000 per well, when several are to be drilled at once. Pumping rig and steam plant will, under the same conditions, add about $1000 per well, and general improvements another $1000, bringing cost per completed well to about $5000. In Sunset the average depth is somewhat less, but cost per well would be about the same as at Kern; in the Midway there is much more range of depth, and costs would run from $5000 to $10,000; at McKittrick, about the same; and at Coalinga, from $4000 to $8000. Costs, of course, vary largely with location and other circumstances, but it might be safe to estimate the average cost per producing well at from $6500 to $7000 in the larger producing fields. Wildcatting is, of course, much more expensive. Land values run from $3500 to $5000 per acre in the better parts of Kern River; from $500 to $1000 at Sunset; in Midway, as high as $1000; at Coalinga, from $250 to $4000 or $5000. At Kern it is customary to allow from one to two acres to each well; at Sunset, about the same; at Coalinga, from one to four acres.

Land Titles.—The larger part of the State was originally the property of the Federal government. This public land is divided into townships, approximately six miles square, and with lines running about parallel to the lines of latitude and longitude. These townships are divided into sections, each one mile square, as near as may be. The earlier railroads (the Central Pacific and the Southern Pacific) were granted, as subsidies, each odd-numbered section for forty miles on each side of their roadbed, and these sections, an enormous area in total, were deeded or "patented" to them by the Government. Almost all the oil fields cover more or less of this railroad land. In the agricultural districts much of the land has been taken up on "homestead entry," that is, has been deeded to settlers by the Government in consideration of certain specified improvements and a nominal purchase price. Vacant government land may also be "located" under the placer mining laws, and on the discovery of mineral (with which petroleum is classed) and the performance of certain requirements, will be deeded to the discoverer by the Government. The holder of a Government deed or "patent" has an unassailable title, but this, of course, loses its force as the title passes from hand to hand. In the southern part of the State, and along the coast, considerable land is held on title acquired from grants by the original Spanish government and from original settlement, and these titles offer nothing out of common. On account of the newness of the country and the large amount of land held by original patentees, it is probably easier to get a good title here than in almost any other part of the United States. This, however, applies only to land held in fee, by patent or otherwise, it being rather difficult to clear title to land held by location, but not yet patented.

CHAPTER 3.

FIELD OPERATIONS.

During the latter part of 1900, the California State Mining Bureau issued a bulletin (Bulletin 19) which set forth in much detail the developments up to that time in all the fields, both producing and prospective. The date of issue of this bulletin was during the height of the oil excitement, and much prospect work has since been done, covering in all twenty-six counties. To describe this work in detail would require a large volume, and would be devoid of present interest, as most of the prospecting was fruitless of result, and has ceased, for the time at least.

The following table (No. 3) shows the number of wells drilled in each county, and such data as are at hand regarding the results. In such counties as contain actually producing fields, the latter have been kept separate, and the figures given for the county at large apply only to that portion of the county outside the bounds of producing fields, as shown by maps on following pages.

It should be noted that, while the numbers of producing wells stated are believed to be accurate, and while care has been taken in compiling all the figures, those for abandoned wells outside of producing fields should not be taken too literally. Some work has undoubtedly escaped observation: In Los Angeles and Ventura counties, in particular, the records are so scattering that the numbers stated for abandoned prospect holes are doubtless too small. Further details as to producing fields will be found on pages facing the corresponding maps.

TABLE 3. RECORD OF FIELD OPERATIONS TO DECEMBER 31, 1903.

County.	Producing Wells ...	Abandoned Wells	Wells Drilling	Wells of Doubtful Value.....	Remarks as to Results.
Alameda	0	7	----------	0	Nothing.
Butte	0	2	0	0	Slight traces of oil.
Colusa	0	18	----------	0	Traces of green and amber oils.
Contra Costa	0	17	----------	0	Traces of medium green oil.
Fresno	0	31	----------	0	Traces of green and black oils.
Coalinga field	110	64	33	6	
Glenn	0	3	0	0	Traces of oil reported.
Humboldt	0	14	0	0	Numerous traces of light oil.
Inyo	0	1	0	0	Nothing.
Kern	0	84	----------	7	Numerous traces of black oil.
Kern River field	798	115	34	16	
Sunset field	102	62	6	8	
Midway field	24	38	6	7	
McKittrick field	75	50	11	25	
Kings	0	20	0	0	Traces of green and black oils.
Los Angeles	49	114[3]	----------	----------	
City field	1079	71[1]	14	90	
Whittier field	99	46	6	4	
Puente field	79	4[1]	0	0	
Newhall field[2]	22	11	1	6	
Napa	0	5	0	0	Traces of 15° green oil.
Orange	0	9	----------	0	
Fullerton field	138	15	14	3	
Riverside	0	3	0	0	Nothing.
San Benito	0	47	0	2	Traces of medium green oil.
San Bernardino	0	8[4]	1	0	
San Diego	0	10	0	0	Nothing.
San Luis Obispo	0	11[4]	0	1	Traces of black oil.
San Mateo	9	14[4]	2	3	
Santa Barbara	----------	38[1]	0	0	Traces of heavy oil at several points.
Summerland field	198	100	0	114	
Santa Maria field	21	10	18	2	
Santa Clara	3	30	2	1	Black oil, 19°.
Santa Cruz	0	11	0	0	Some gas in one well.
Shasta	0	3	0	0	Nothing.
Solano	0	3	0	1	Some gas in one well.
Stanislaus	0	3	0	0	Nothing.
Tehama	0	2	0	0	Nothing.
Ventura[5]	----------	37[4]	----------	----------	Oil and gas in several wells.
Ventura[6]	308	144	11	26	
Totals	3098	1271	159	322	

[1] This figure is undoubtedly too small.

[2] Only the portion shown by map—does not include Wiley and Pico.

[3] Partly estimated.

[4] Probably too small.

[5] Outside of mapped district.

[6] District covered by map only.

FULLERTON.

The Fullerton oil field lies at the northeast corner of Orange County, where the latter abuts Los Angeles and San Bernardino counties. Present production is entirely from Orange County.

The main portion of the field occupies a trough-like valley, bounded on the south by the southernmost spur of the Puente Hills, and on the north by the main range. The elevation of the valley floor above sea level is about 550 feet, the hills rising from 200 to 300 feet higher.

The geological formation is said to be of Middle Neocene age, and to be a regular anticline, with axis lying east and west through the approximate center of the developed field. Depth of wells varies from 1000 feet to nearly 4000 feet, according to position of well on dip of producing strata. Both limbs of the anticline are productive, but the oil obtained on the north dip averages about 8° lighter than that from the south, while the oil is also lighter at the eastern end than at the western. The boundaries of the field do not seem to have been certainly determined in any direction, though owing to the great depth to which drilling has been carried, and to the high gas pressure, many wells have been spoiled.

NOTE REGARDING MAPS.—The intention in preparing these maps was to note developments rather than to show land holdings. For this reason no titles are shown except on plots containing one or more producing wells. Further, the titles and bounds of named plots are largely taken from other sources than direct inquiry, and while believed to be in the main correct, are not guaranteed to be accurate.

The discrimination between producing and abandoned wells is often a difficult, always a delicate matter. In such a field as Coalinga, where the market for oil is ample, it is safe to say that any well not being pumped is incapable of producing, and may be set down as abandoned, allowing of course for cleaning operations, etc., on producing wells, which are evident enough. But in such fields as Sunset or Midway, where practically no oil is being pumped, it is a matter of much difficulty to determine which wells are capable of production.

To relieve this difficulty somewhat, the half-black mark has been adopted. This mark indicates a doubt as to producing value, or the lack of definite information. In Los Angeles, Whittier, Fullerton, Newhall, McKittrick, and Kern River, this mark is intended to indicate that the well is not pumping, while others nearby are at work; the presumption is that such wells are not profitable at present, yet there seems reason to believe that they might become producers under more favorable circumstances. In Summerland the mark indicates wells not being pumped, but which have not been abandoned, while wells from which pumping rigs have been removed are placed in the abandoned class. In Sunset and Midway wells so marked are rigged, but there is no information that they have ever produced commercial quantities of oil. In Ventura County the mark indicates that more definite information was not available.

In cases where unfinished wells are rigged for drilling, the well is noted as drilling if work had been done on it within six months previous to examination, as abandoned if no work had been done during that period.

In preparing these maps, use has been made of maps of Messrs. J. B. Lippincott and E. D. Severance, and of the Central Oil Company of Los Angeles, of the Santa Fé Railroad at Fullerton, and of Messrs. Barlow and Hill of Bakersfield, while thanks are extended for much valuable information to Messrs. Wm. Plotts and W. E. Bacon of Whittier, and Mr. H. L. Dort of Bakersfield.

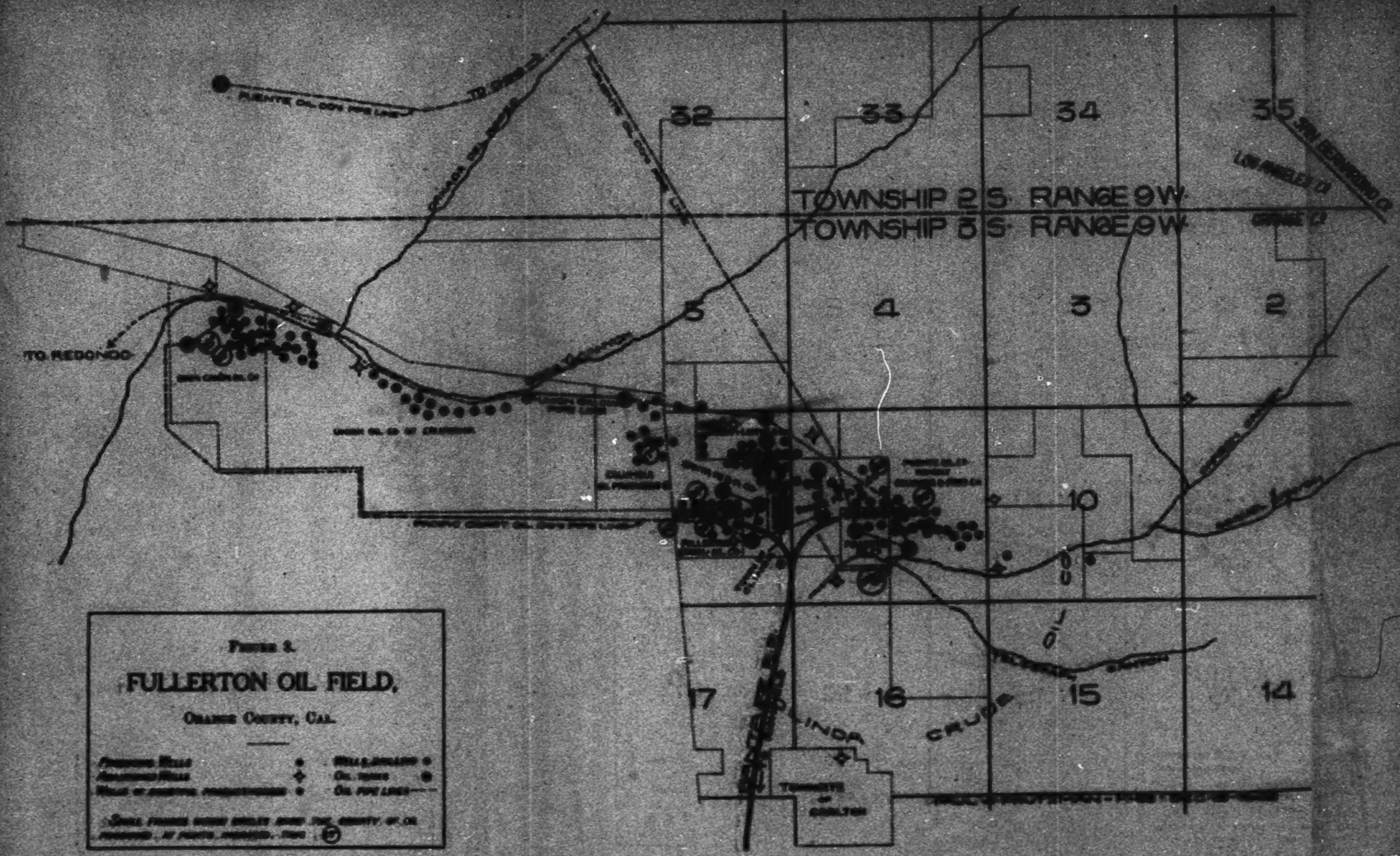

FUENTE OIL CO'S PIPE LINE
TO REDONDO
32
33
34
35
SAN BERNARDINO CO
LOS ANGELES CO
TOWNSHIP 2 S. RANGE 9 W.
TOWNSHIP 3 S. RANGE 9 W.
ORANGE CO
5
4
3
2
10
17
16
15
14
OIL
LINDA
CRUDE
Oil pipe lines

Figure 3.

FULLERTON OIL FIELD,

Orange County, Cal.

No. 2. Brea Cañon—Looking South.

No. 3. Puente Hills—From the South Fork of the San Gabriel Valley, Los Angeles County.

The Brea Cañon wells appear to be on an extension of the north limb of the anticline, which here approaches the surface, the south limb being eroded away; this is not certain. These wells are close to extensive brea deposits, which follow the south slope of Brea Cañon, and naturally produce rather heavy oil.

The oils of Fullerton are produced from beds of fine incoherent sand, the heavier oils raising considerable of it to the surface at some points. Extreme range of gravity is from 14° to 35°, location of various gravities being indicated on the map herewith. The lighter oils are highly valuable for refining, the heavier are used for fuel; most of the output of both kinds goes to Los Angeles by rail, though some of the light oil is piped to the refinery at Chino.

A branch of the Union Oil Company's pipe-line to San Pedro enters the field from the west, and there are numerous pipe-lines connecting various parts of the field with the railroad. The Santa Fé Railroad has a branch to Olinda station, in the field proper, from Richfield, distant four miles. The distance from Los Angeles, by railroad, is thirty-five miles; to the coast at Anaheim, in a straight line, twenty miles.

STATISTICS. (December 13, 1904.)

Number of wells producing	138
Number of wells drilling	14
Number of wells not producing. (See explanatory note.)	3
Number of wells abandoned	15
Approximate area producing	1200 acres.
Gravity of oil	Maximum, 35°; Minimum, 14°; Average, 22° Be.
Approximate present price at wells, per barrel—	
Fuel oil	60 cents.
Lighter grades	75c to $1.75

PUENTE.

The Puente oil field is situated near the southeast corner of Los Angeles County, the wells, which are all in one group, lying just north of the line between Los Angeles and Orange counties, and some seven miles west of the line between Los Angeles and San Bernardino counties. The wells farthest east in the Puente group are less than one mile northwest from the westernmost wells in the Brea Cañon extension of the Fullerton field.

The wells in the Puente group are scattered over an area of nearly two square miles, well up on the south slope of the hill range of the same name, the lowest wells being some 1000 feet above sea level, the highest some 1250 feet.

The geology of the Puente Hills, which include the Whittier, Puente, and Fullerton oil districts, is described in detail in Bulletin 19 of the

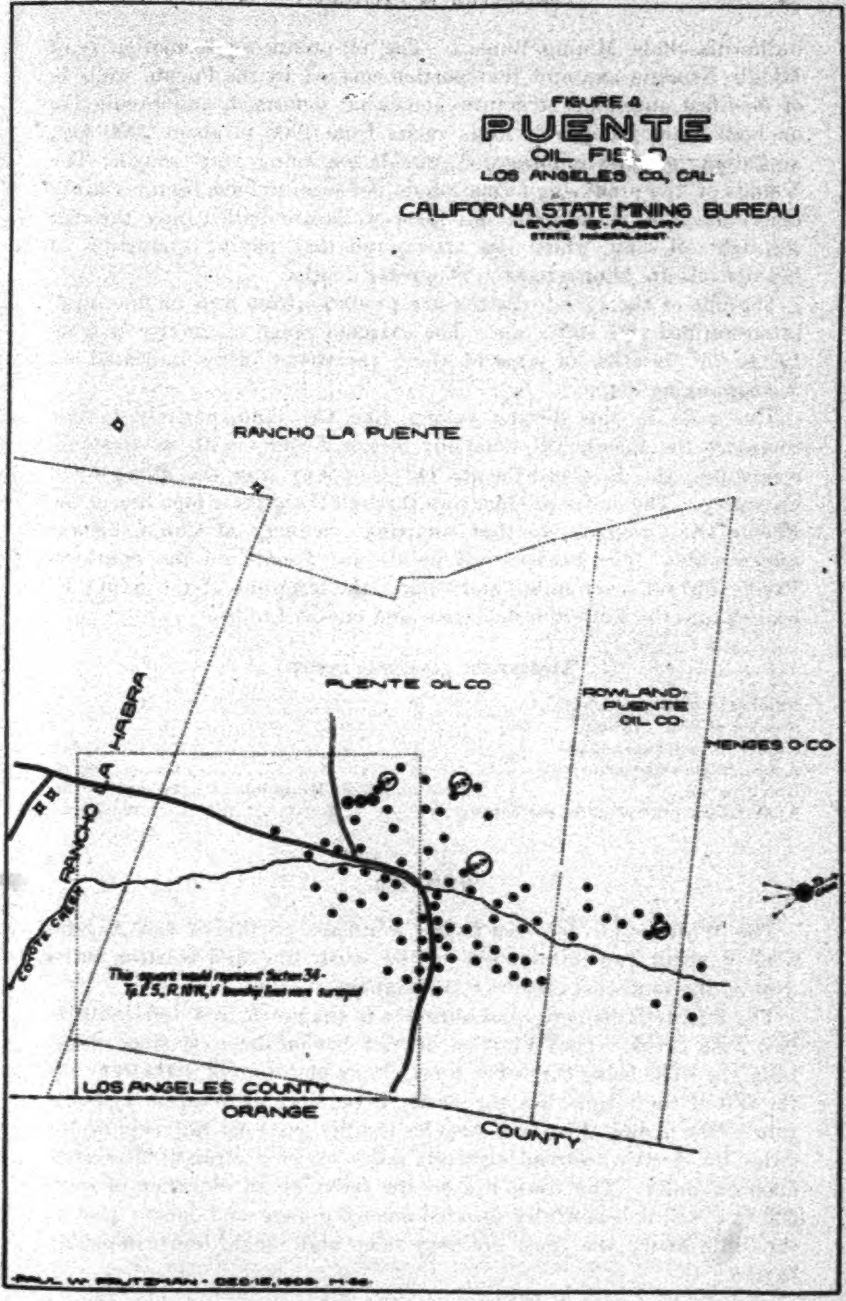


FIGURE 4
PUENTE
OIL FIELD
LOS ANGELES CO., CAL.
CALIFORNIA STATE MINING BUREAU
LEWIS E. AUBURY
STATE MINERALOGIST

RANCHO LA PUENTE
RANCHO LA HABRA
PUENTE OIL CO
ROWLAND-PUENTE OIL CO.
HENGES O. CO.
COYOTE CREEK
This square would represent Section 34 - Tp. 2 S., R. 11 W., if township lines were surveyed
LOS ANGELES COUNTY
ORANGE COUNTY
PAUL W. PRUTZMAN · DEC. 12, 1908 · H-66

California State Mining Bureau. The oil-producing formation is of Middle Neocene age, and that portion covered by the Puente wells is of modified anticlinal structure, somewhat deformed, and productive on both limbs. Depth of wells varies from 1000 to about 2000 feet, according to surface formation, the latter being very rough. The bounds of the producing formation do not seem to have been certainly determined. It is said that all these wells are drilled only through the light oil sand, which lies above, and that paying quantities of heavier oils are known to exist at greater depths.

The oils of the Puente district are produced from beds of fine sand, interstratified with soft shale. The extreme range of gravity is from 18° to 33°, location of some of these variations being indicated on accompanying map.

The wells in this district belong, like the land, entirely to one company, the Puente Oil Company of Los Angeles, with its two subcompanies, the Rowland-Puente Oil Company and the Menges Oil Company. The entire product goes through the private pipe-line of the Puente Oil Company, to that company's refinery at Chino, distant fifteen miles. The nearest rail points are Puente, on the Southern Pacific, distant seven miles, and Olinda, the terminus of the Santa Fé branch into the Fullerton field, four and one half miles.

STATISTICS. (December 13, 1903.)

Number of wells producing	79
Number of wells drilling	0
Number of wells abandoned	4(?)
Approximate area producing	2 sq. m.
Gravity of oil	Maximum, 33°; Minimum, 18°; Average, 27° Be.
Approximate price at wells, per barrel	None sold.

WHITTIER.

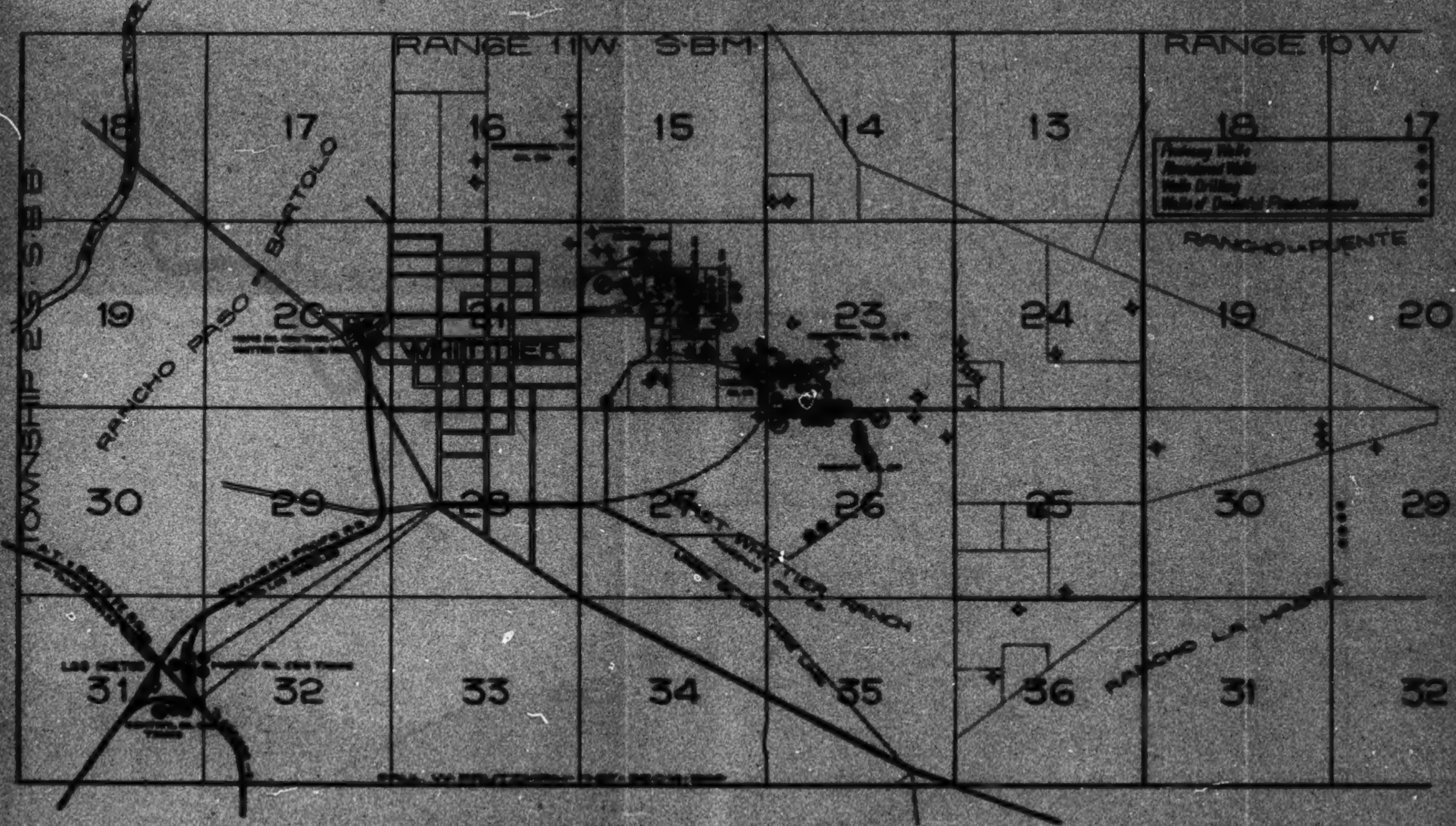
The Whittier oil field lies in the southeast portion of Los Angeles County, about two miles north of the south line, and thirteen miles west of the southeast corner of the county.

The Puente Hills here bend abruptly to the north, and terminate at San José Creek. The Whittier district lies on the west slope of the hills, the wells being carried to a maximum elevation of 1000 feet. At the foot of these hills lies the pretty little town of Whittier (population 1600), distant from Los Angeles (to the east) by rail twenty-one miles, by electric railroad eighteen miles, or in a straight line some fourteen miles. The town lies on the mesa, at an elevation of some 600 feet, and is beautifully situated among orange and lemon groves; the hills above the town are very steep and rough, and completely barren.

FIGURE 5.

WHITTIER OIL FIELD.

LOS ANGELES COUNTY, CAL.


RANGE 11 W S.B.M.
RANGE 10 W
TOWNSHIP 2 S S.B.B.
18
17
16
15
14
13
18
17
Producing Wells
Abandoned Wells
Wells Drilling
Wells of Doubtful Productiveness
RANCHO LA PUENTE
19
20
21
23
24
19
20
WHITTIER
RANCHO PASO DE BARTOLO
30
29
28
25
26
25
30
29
WEST WHITTIER RANCH
RANCHO LA HABRA
SOUTHERN PACIFIC R.R.
LOS NIETOS
31
32
33
34
35
36
31
32

No. 4. FULLERTON—LOOKING EAST FROM SEC. 8, 3 S., 9 W.

No. 5. WHITTIER—WELLS ON SEC. 22, 2 S., 11 W.

The geological formation is of Middle Neocene age, the producing strata having the form of a steeply tilted plane, and outcropping farther up the hills. The depth of wells varies greatly: from a few hundred feet near the line of outcrop, to twenty-two hundred feet or more in the wells farthest down the dip. The productiveness increases rapidly as greater depths are reached, and on the west the extension of the field is limited solely by the difficulty of drilling. To the north the field appears to have reached its limits; to the northeast it is bounded by the cropping of the sands; to the southeast, though a number of failures have been recorded in that direction, there appears to be a possibility of extension.

The character of the formation penetrated is principally hard conglomerate, with considerable water, and for this reason drilling is difficult and expensive, requiring the heaviest and best rigs and machinery. Oil is produced from a hard sandy conglomerate, and carries no sand. This is probably the only district of any importance in the State which produces oil from a hard formation, though limited areas in Ventura County have the same characteristic. The gravity of oil produced varies somewhat, principally with the location of the sand (of which there are several layers) from which the supply is drawn. The superficial position of the well on the sand does not appear to have much influence, though the gravities are probably rising somewhat as drilling goes down the dip. A single well produces an oil far heavier than the average, though surrounded by ordinary wells; the anomaly does not seem to have been explained.

The Union Oil Company's pipe-line to the coast enters the field at the northwest, and is connected to most of the leases. Several companies at this end of the field also have pipe-lines to Whittier station on the Southern Pacific, while the two larger companies at the southeastern end have pipe-lines to Los Nietos station, at the intersection of the Santa Fé and the Southern Pacific; distant from the field about three miles, from Los Angeles nineteen miles. All the oil from Whittier, except that taken by the Union Oil Company's pipe-line, goes to Los Angeles, where the larger part is refined.

STATISTICS. (December 10, 1902.)

Number of wells producing	50
Number of wells drilling	6
Number of wells of uncertain value	4
Number of wells abandoned	45
Approximate area producing	1.5 sq. m.
Gravity of oil	Maximum, 24°; Minimum, 14°; Average, 19° Be.
Approximate present price at wells, per barrel	60 cents.

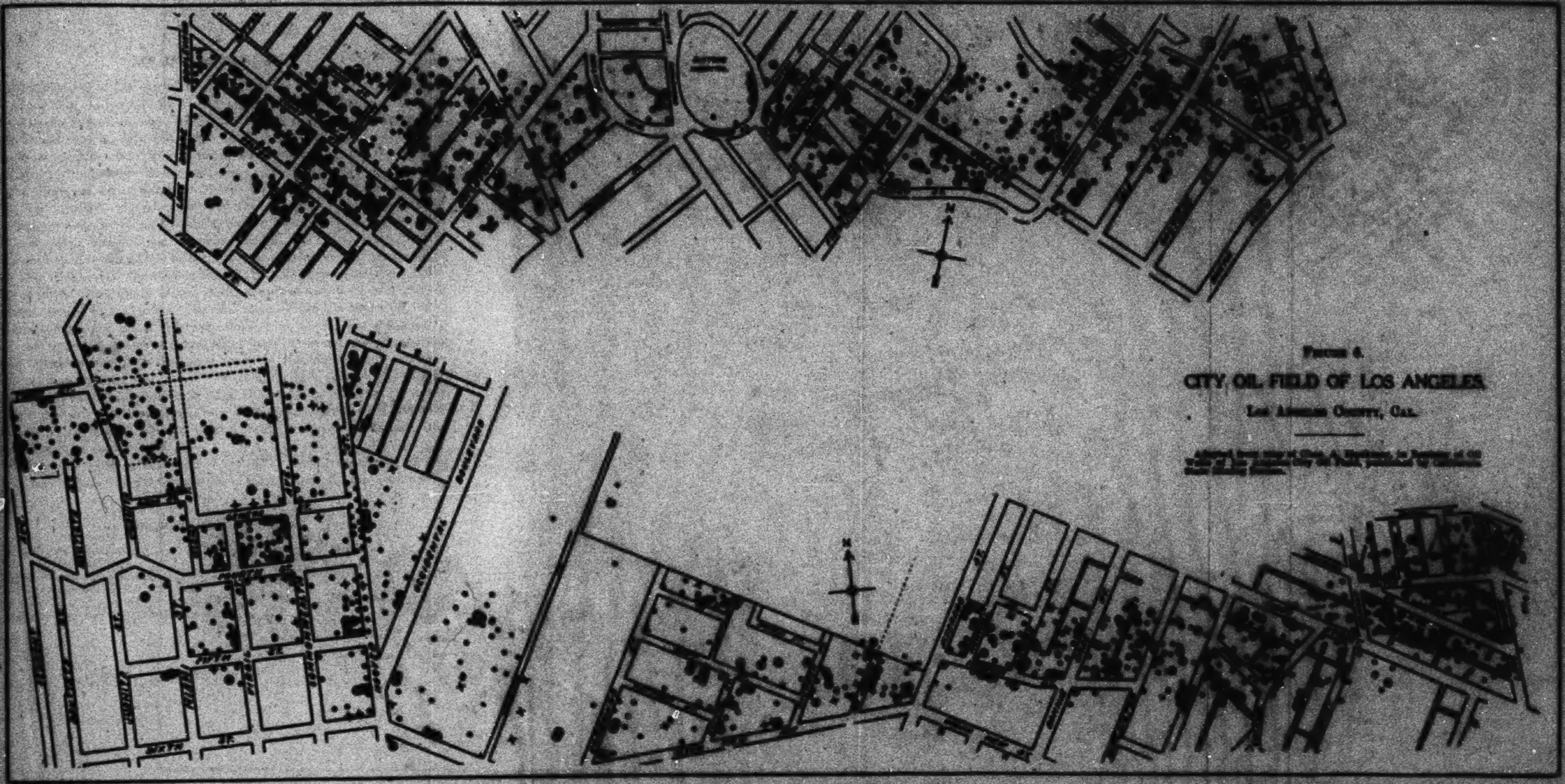

N
N
SIXTH ST.
FIFTH ST.

FIGURE 6.

CITY OIL FIELD OF LOS ANGELES.

LOS ANGELES COUNTY, CAL.

Adapted from map of [illegible] of Oil wells of [illegible] City Oil Field, published by California State Mining Bureau.

LOS ANGELES CITY FIELD.

The City field of Los Angeles is peculiar in that it is situated, not merely within the city limits, but in a thickly settled residence district. Los Angeles is built on low, rolling hills, and over these hills the oil field stretches in a strip over three miles long, varying in width from one fourth to three fourths of a mile, running a little north of east and south of west, through the northwestern part of the city.

The geological formation is of Middle Neocene age, and has the form of a flat anticline, though somewhat broken. At the western end the sands approach the surface, some wells here being as little as 300 feet in depth; still farther west the sands crop. At the eastern end the greatest depth is some 1500 feet, the average being one or two hundred feet less; this end of the field is cut off abruptly, apparently by a fault. The production is greater at the eastern end of the field, and the oil lighter, though in all parts of the field the product is a heavy oil. The production per day per well is very small, even in the best wells, probably owing to the excessive crowding. Oil is produced from incoherent sand interstratified with clay, and many of the wells pump considerable sand and water.

Owing to the location of the field in the midst of a large city, there are no pipe-lines of any length, nor do the railroads touch the field directly at any point. The oil is used locally, principally for fuel, and is delivered by tank wagon.

The greater part of the wells in the City field are pumped on the jack, the wells of several owners often being handled from one power.

STATISTICS. (December 10, 1905.)

Number of wells producing	979
Number of wells drilling	14
Number of wells not producing	90
Number of wells abandoned	71
Gravity of oil	Maximum, 16°; Minimum, 11°; Average, 13.5° Be.
Approximate present price at wells, per barrel	70 cents.

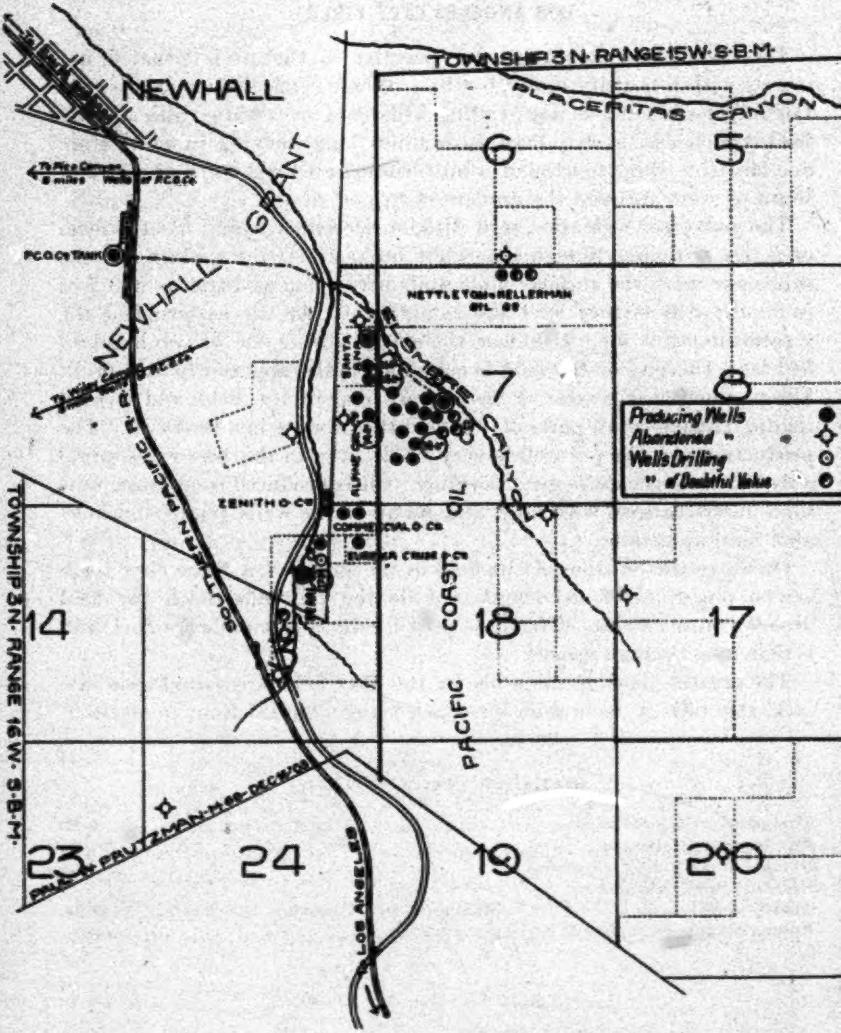

NEWHALL
TOWNSHIP 3 N· RANGE 15 W· S·B·M·
PLACERITAS CANYON
To Pico Canyon 8 miles
Wells of P.C.O.Co.
P.C.O.Co TANK
NEWHALL GRANT
To Wiley Canyon
NETTLETON & KELLERMAN OIL CO
ELSMERE CANYON
SANTA ANA
ALPINE
ZENITH O. Co
COMMERCIAL O. Co.
EUREKA CRUDE Co
PACIFIC COAST OIL Co
SOUTHERN PACIFIC R. R.
TOWNSHIP 3 N· RANGE 16 W· S·B·M·
DALY & PRUTZMAN-H.69-DEC.14'08
LOS ANGELES
6
5
7
8
14
18
17
23
24
19
20
Producing Wells
Abandoned "
Wells Drilling
" of Doubtful Value

Fig. 7. Eastern portion of Newhall Oil Field, Los Angeles County, Cal.

NEWHALL.

The Newhall oil field, or properly group of fields, lies in the western portion of Los Angeles County, being some ten miles east of the Ventura county line, and some twenty-five miles northwest of Los Angeles city.

The wells in the Newhall district are situated in several cañons in the higher part of the San Fernando Mountains, the elevation ranging from 1300 to 1700 feet. The town of Newhall, on the Southern Pacific Railroad, distant thirty miles from Los Angeles, occupies a small area of flat land in the center of this territory.

The wells in Pico Cañon, belonging to the Pacific Coast Oil Company, are some six miles due west of Newhall. They are in a very rough, hilly country, vary in depth from 700 to 950 feet, and produce an oil of some 41° gravity from sandstone streaked with shale. (Bulletin 19, California State Mining Bureau.)

There are also a few wells, belonging to the same parties, in Wiley Cañon, about three miles southwest of Newhall. These wells range in depth from 600 to 1600 feet, and produce an oil of about 30°, from shale and sandstone. (Bulletin 19, California State Mining Bureau.)

In Placeritas Cañon, some four miles due east of Newhall, there were at one time several wells producing a light oil from conglomerate, shale, and crushed granite. The wells proved to be short lived, and there is said to be no production whatever from this district, at the present time.

In Elsmere Cañon and on the hills to the southwest, there are a number of wells producing heavy black oil (from 14° to 16°) from coarse sand and fine gravel. The depth of these wells ranges from 400 to 1000 feet. These wells are some three miles southeast of Newhall.

The Newhall field derives its principal importance from the old wells in Pico Cañon, and from these principally because of their age and of the high gravity of their product. The production over this entire district is small. From Pico and Wiley cañons the oil is taken into the Pacific Coast Oil Company's pipe-line, running east to the ocean at Ventura, through the Santa Clara Valley. The oil from Elsmere and vicinity goes through a pipe-line to the railroad near Newhall station, and from thence to Los Angeles by rail.

Most of the wells in all parts of the Newhall field are pumped by means of the jack.

STATISTICS. (December 20, 1903.)

Number of wells producing	55
Number of wells drilling	3
Number of wells of uncertain value	6
Number of wells abandoned	31
Approximate area producing	1.4 sq. m.
Gravity of oil	Maximum, 41°; Minimum, 12°; Average, 25° Be.
Approximate present price at wells, per barrel	None sold.

No. 6. Los Angeles City—East End.

No. 7. Newhall—Looking North from Sec. 13, 3 N., 16 W.

No. 8. Newhall—Pico Cañon Wells.

No. 9. Newhall—Pico Cañon Wells.

SUMMERLAND.

The Summerland oil field is situated on the shore of the Pacific Ocean, six miles southeast of Santa Barbara, and in the county of the same name.

The wells are, for the most part, directly along the shore line, both on the beach itself and on a low bank of clay back of it. Many, however, have been sunk farther out than low tide, from light wharves, and there are also a few farther back, in the town.

The oils of this district are produced from loose sands, interstratified with clay, of Middle Neocene age. Depths vary from 150 to 300 feet, though there are a few deeper, one being 600 feet. Two holes of greater depth have been drilled, on the north side of the field, in the attempt to find a lower sand, but these wells are not productive. The dip of the sand follows, in a general way, that of the ocean bottom, and the deeper wells are the better producers, giving also a rather lighter oil. The difference in gravity, however, is small, the range being not greater than from 10.5° to 15.5°. Most of the wells, the shallower ones more particularly, raise a good deal of sand and water.

The bounds of the field have been determined on all sides, and in fact have contracted considerably during the last two years. As may be seen from the accompanying map, very few wells are being pumped on the town side of the railroad, and a number of plants are idle at the eastern end of the field. At one time there was considerable gas from these sands, and a number of wells were sunk for gas alone, but the production has now fallen very low, the pressure being so light that, it is said, the flow ceases with any considerable rise in the barometer.

A considerable portion of the oil from this district is used by the local refinery, in the manufacture of asphalt, this oil being particularly suitable for this use. The balance goes to Santa Barbara, by rail, for fuel. At Serena, distant about one mile, there is a wharf running out to deep water, but this is rarely used.

All the wells at Summerland are pumped on the jack.

STATISTICS. (December 24, 1903.)

Number of wells producing	198
Number of wells drilling	0
Number of wells not producing	114
Number of wells abandoned	100
Gravity of oil	Maximum, 15.5°; Minimum, 10.5°; Average, 14° Be.
Approximate present price at wells, per barrel	80 cents.

FIGURE 3.

SUMMERLAND OIL FIELD

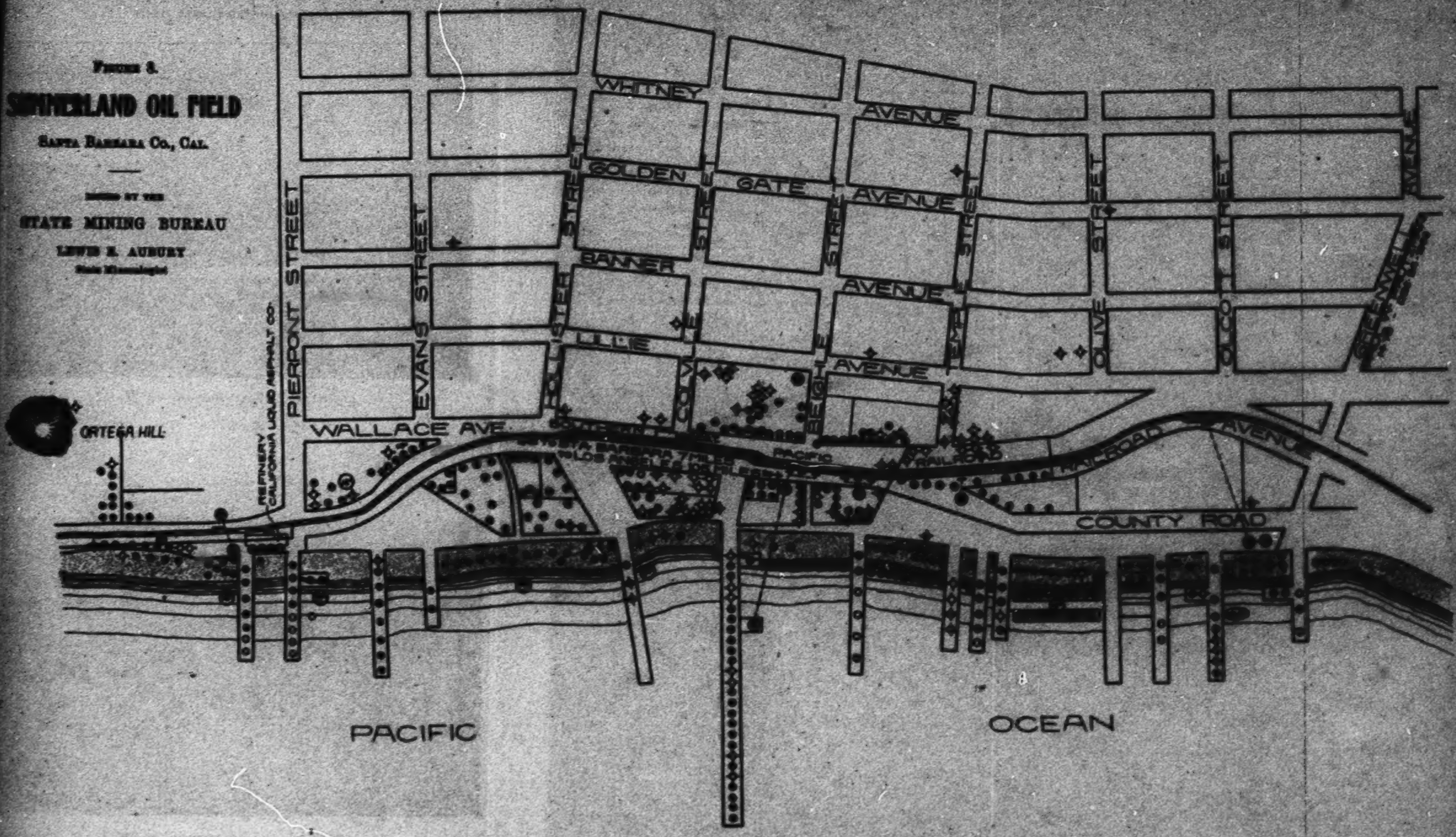
SANTA BARBARA CO., CAL.

ISSUED BY THE

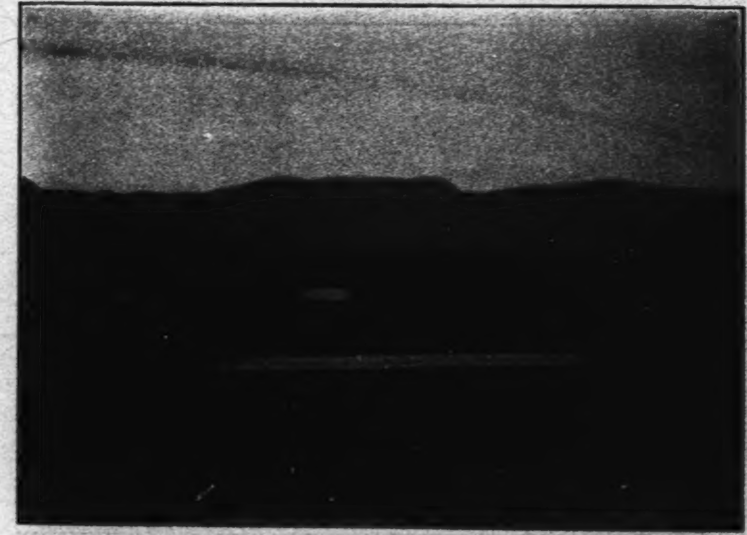
STATE MINING BUREAU

LEWIS E. AUBURY

State Mineralogist



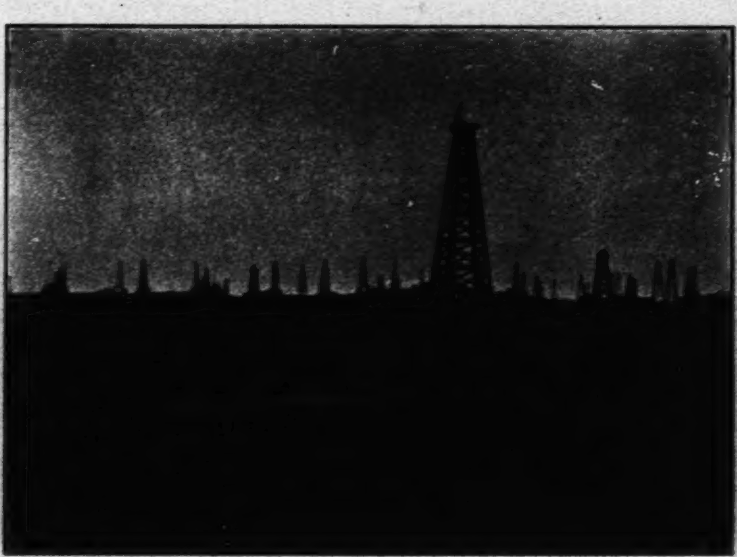
WHITNEY AVENUE
GOLDEN GATE AVENUE
BANNER AVENUE
LILLIE AVENUE
WALLACE AVE
PIERPONT STREET
EVANS STREET
STREET
STREET
STREET
STREET
STREET
OLIVE
OLCOTT
GREENWELL AVENUE
AVENUE
COLV
BEIGH
ORTEGA HILL
REFINERY CALIFORNIA LIQUID ASPHALT CO.
SANTA BARBARA 7 MILES
TO LOS ANGELES 106 MILES
PACIFIC RAILROAD
RAILROAD AVENUE
COUNTY ROAD
PACIFIC
OCEAN



No. 10. Summerland—From the Ocean.

No. 11. Summerland—From the Shore.

No. 12. Kern River—Looking North from Sec. 5, 29 S., 28 E.



No. 13. Kern River—Looking South from Center of Section 32.

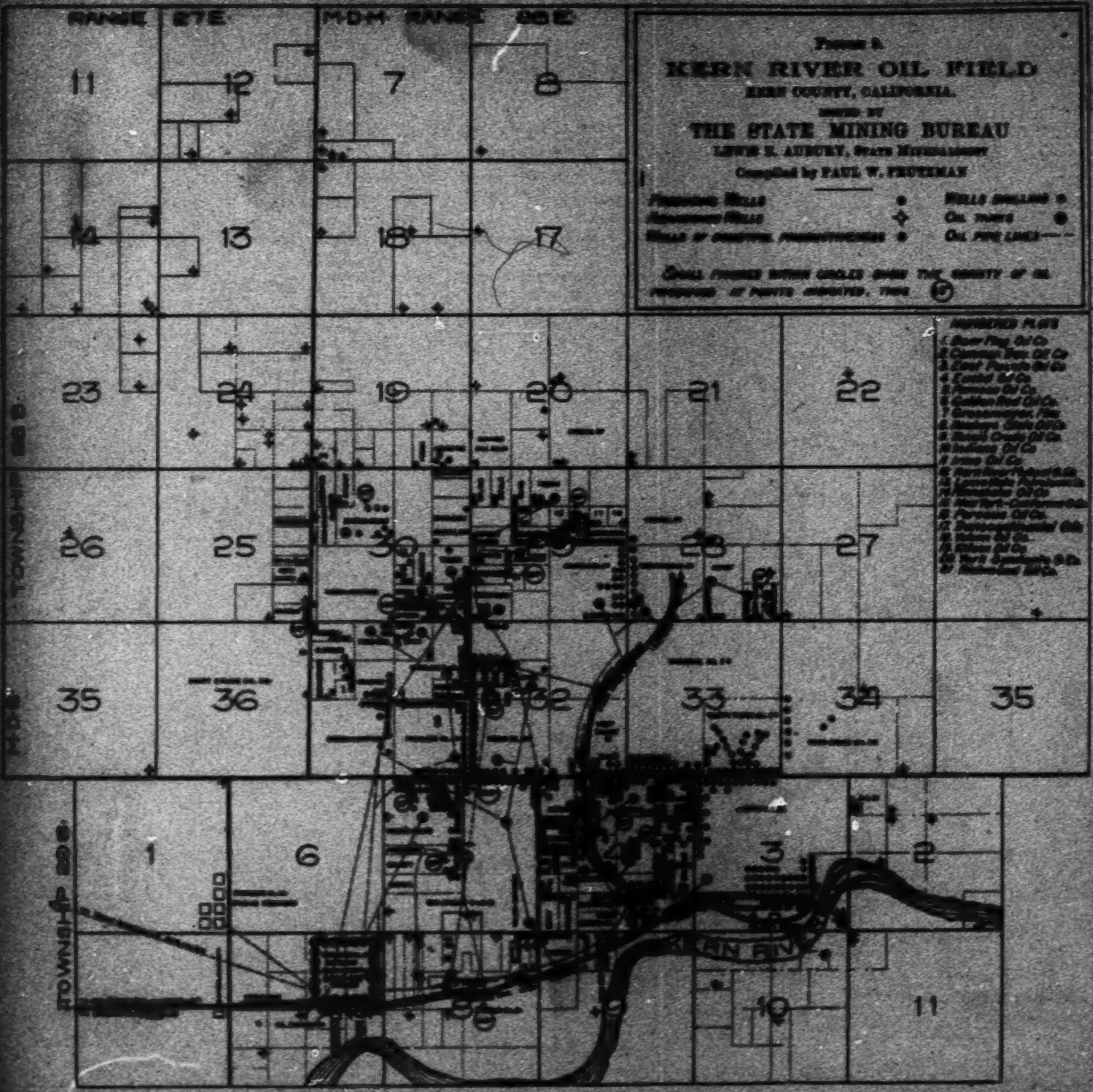


Figure 9.
KERN RIVER OIL FIELD
KERN COUNTY, CALIFORNIA.
ISSUED BY
THE STATE MINING BUREAU
LEWIS E. AUBURY, State Mineralogist
Compiled by PAUL W. PRUTZMAN
Producing Wells
Abandoned Wells
Wells drilling
Oil tanks
Oil pipe lines
NUMBERED PLATS
1. Bear Flag Oil Co
RANGE 27E
M.D.M. RANGE 28E
TOWNSHIP 28 S
M.D.B.
TOWNSHIP 29 S
KERN RIVER
11
12
7
8
14
13
18
17
23
24
19
20
21
22
26
25
30
28
27
35
36
32
33
34
35
1
6
3
2
8
9
10
11

KERN RIVER.

The Kern River oil field, by far the most important in the State in point of production, is situated in the eastern portion of Kern County, and at the eastern margin of the San Joaquin Valley.

The producing wells cover an area about three and one half miles square, in the low foothills of the Greenhorn Mountains, the latter a spur of the Sierra Nevada. Kern River, a shallow tributary of the San Joaquin River, follows, and in a sense forms, the southern boundary of the field. The river banks here have an altitude of about 450 feet, while north the hills reach a maximum height of about 950 feet. The nearest town of any importance is Bakersfield, distant three miles in a straight line, but eleven miles by railroad. The oil-producing formation is extremely regular, in shape approximating that of a flat saucer, inverted, and with its eastern rim somewhat raised. Depth of wells varies from 600 to 1200 feet, being least at the eastern margin of the field, and greatest at the western. The oil is produced from beds of incoherent sand, alternating with clay and shale streaks, both of which are remarkably persistent, over the entire producing area. The greatest thickness of paying sand is at the center of the field, where the net sand averages 350 feet; toward the edges the sand thins out, the percentage of saturation falls, and the gravity of the oil lowers somewhat. The

No. 14. Tanks of Pacific Coast Oil Co. and Loading Racks—Kern River Oil Field.

bounds of the Kern River field have been definitely determined in all directions.

The gravity of oil produced over this area is remarkably uniform, the variation being from 11.8° to 17.0°, with the exception of a single well producing oil of 10.5°. In general, the lighter oil is in the upper, though not the uppermost, sands, while at the bottom a thin stratum carries a very heavy oil; water sands are found both above and below the oil. Aside from the oil converted into asphalt and crude distillate by the seven local refineries, the entire output of this field is used for fuel, principally at or near San Francisco.

The Pacific Coast Oil Company has an eight-inch pipe-line connecting the Kern River field with Point Richmond, a station on the eastern shore of San Francisco Bay, distant from San Francisco nine miles by water, and from Kern River two hundred and seventy-eight miles. This line is not at present in operation. There are numerous pipe-lines connecting all parts of the field with the railroad and the refineries. A railroad spur, used jointly by the Southern Pacific and the Santa Fé, extends from Bakersfield, a distance of some fourteen miles, making the distance by rail to San Francisco some three hundred and twenty-five miles, and to Los Angeles some one hundred and eighty-five miles. The distance from tide water is about one hundred miles in a straight line, but considerable rough mountain country intervenes, and there is no present outlet in that direction.

In the southeastern portion of the field, where the wells are shallow, and the production per well is comparatively light, many wells are being jacked, but in other parts of the field practically all wells pump on the beam. The oils in almost all parts of the field raise great quantities of sand, making frequent cleaning necessary.

STATISTICS. (December 2, 1903.)

Number of wells producing	796
Number of wells drilling	34
Number of wells of uncertain value	16
Number of wells abandoned	115
Approximate area producing	9 sq. m.
Gravity of oil	Maximum, 17.0°; Minimum, 11.8°; Average, 15.5° Be.
Approximate present price at wells, per barrel	21 cents.

No. 15. Loading a Tank Steamer.

No. 16. Oil Tanks at Kern River, in Course of Construction.
Capacity, 35,000 bbls. each.

No. 17. Tank Cars. (Capacity, 150 and 200 bbls.)

SUNSET.

The Sunset oil field is situated in the southwestern portion of Kern County, on the eastern slope of the Coast Range Mountains, and at the western side of the San Joaquin Valley.

The wells lie on the lower foothills of the Coast Range, and extend out on the mesa at their base, where are located the stations Pioneer and Maricopa, and railroad station called Sunset. The elevation at Pioneer is 750 feet, and the wells rise to the maximum height of 1025 feet.

The formation is of Middle Neocene age, and is in form an inclined plane, following the dip of the surface, in general. Depth of wells varies from 550 to 1000 feet, according to surface conformation, and to position on the dip; the average depth would fall below 750 feet. The producing strip is a very narrow one, and appears to have been determined on all sides, with the possible exception of the southeast corner.

The oils of Sunset are produced from beds of incoherent sand, varying from moderately fine to very coarse. In different parts of the field the gas pressure is high, and many wells flow when allowed to do so, raising quantities of sand where the latter is fine. Most of the wells penetrate the upper sand only, but a few reach a good second sand, lately discovered; this second sand has been proven in but one portion of the field. The extreme range of gravity is from 17° to 10.5°; the heaviest oil being from the extreme south, near the outcrop of the sands; the lightest from the group of wells on the mesa, near the center of the field, and a medium oil from all parts north. The average gravity is not far from 14°. All the oil produced is used for fuel, except that converted into asphalt and distillate by the refinery near Pioneer. On account of lack of transportation facilities, very little oil is being or has been produced except from wells close to the railroad.

A spur used jointly by the Southern Pacific and the Santa Fé extends from Bakersfield to Sunset, a distance of forty-one miles, and is now being extended to Maricopa, three miles farther north. A pipe-line is also being laid from the northern part of the field to the railroad. There are two or three short pipe-lines to the railroad from nearby wells, but the greater part of the field is without any present means for getting out its product.

All the wells at Sunset are rigged for beam pumping.

STATISTICS. (December 12, 1903.)

Number of wells producing	102
Number of wells drilling	6
Number of wells of uncertain value	8
Number of wells abandoned	62
Approximate area producing	4.2 sq. m.
Gravity of oil	Maximum, 17°; Minimum, 10.5°; Average, 14° Be.
Approximate present price at wells, per barrel—	
17° oil	25 cents.
14° oil	21 cents.

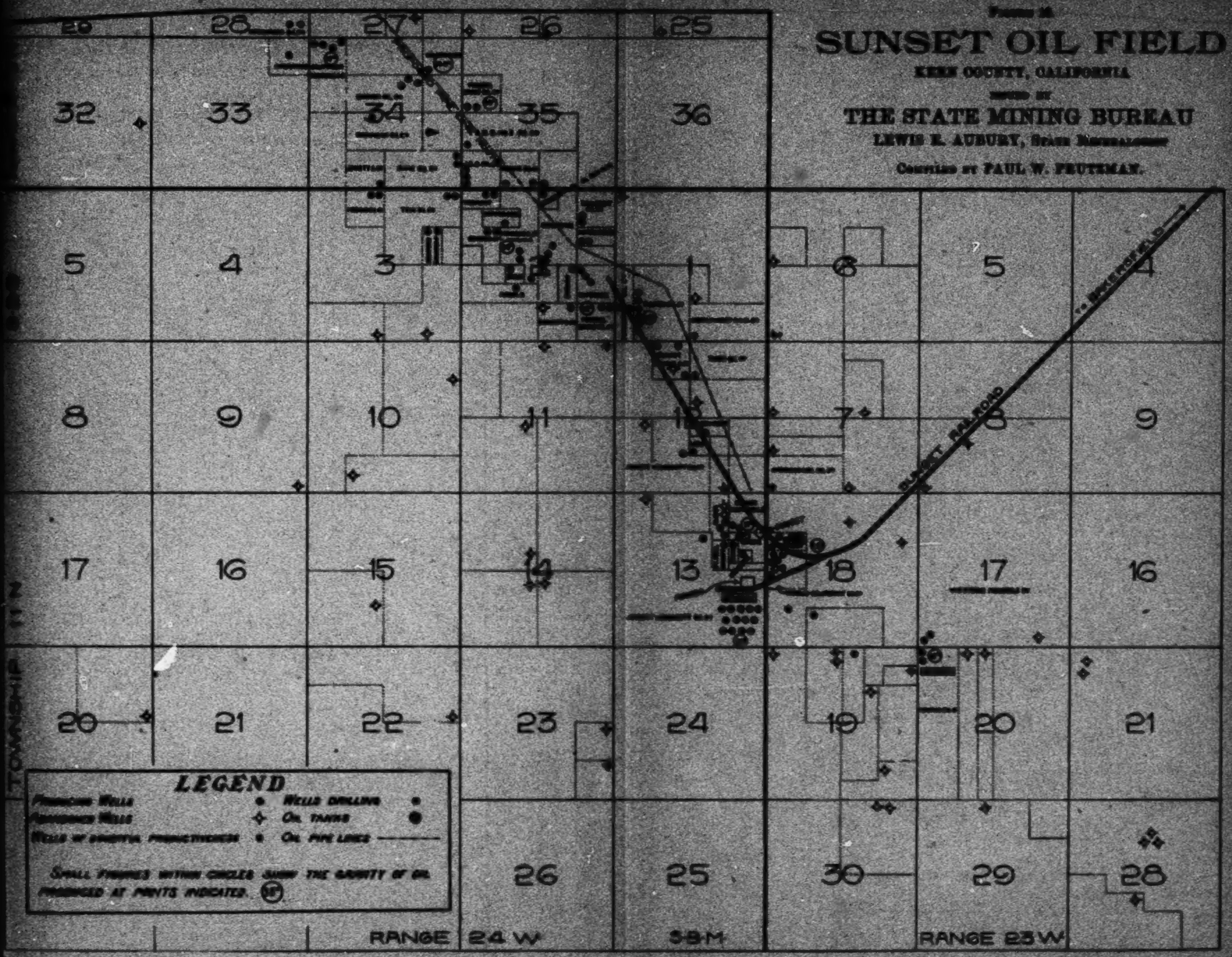


FIGURE 16.

SUNSET OIL FIELD

KERN COUNTY, CALIFORNIA

ISSUED BY

THE STATE MINING BUREAU

LEWIS E. AUBURY, State Mineralogist

Compiled by PAUL W. PRUTZMAN.

LEGEND
Producing Wells ●
Abandoned Wells ✦
Wells of doubtful productiveness ●
Wells drilling ●
Oil tanks ●
Oil pipe lines ——
Small figures within circles show the gravity of oil produced at points indicated.
29
28
27
26
25
32
33
34
35
36
5
4
3
2
1
6
5
4
8
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24
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21
26
25
30
29
28
TOWNSHIP 11 N
RANGE 24 W
S.B.M.
RANGE 23 W
SUNSET RAILROAD
TO BAKERSFIELD

No. 18. Sunset—Looking North from Sec. 13, 11 N., 24 W.

No. 19. Sunset—Looking South from Railroad Depot.

MIDWAY.

The Midway oil field is situated in the southwestern portion of Kern County, on the eastern slope of the Coast Range Mountains, and at the western side of the San Joaquin Valley.

The Midway wells form a narrow line, almost straight, from a point about one half mile north of the northernmost Sunset well, extending northwest for some six miles. The producing strip does not appear to be anywhere more than one mile in width.

The formation is probably of the same age as that of Sunset and McKittrick, *i. e.*, Middle Neocene, but drilling records are too incomplete to give much idea as to its form, or to determine the conditions which limit its productive area. It is probable, however, that it is generally flat, and follows the dip of the surface, as the wells farthest to the west have, in several cases, found the oil sand in place but unproductive, while on the extreme east the oil sand has given place to a water sand. The boundaries of the producing ground seem to be fairly well marked out, but much of the intervening territory is undeveloped, though the work thus far done would give the impression that it is spotty. Depth of wells runs from 600 to 1500 feet, the average being probably over 1000 feet. The surface elevation ranges from 800 to 1200 feet.

The oils of the Midway are produced from beds of incoherent sand, principally of a coarse texture. The gravities range from 14° to 22°, averaging somewhere about 16°. Some of the locations at which these different gravities have been found are noted on accompanying map; the principles governing these variations have not been established.

The Midway district is without transportation facilities of any kind, supplies being brought in from either McKittrick or Sunset. For this reason, practically no oil has been actually produced, most of the wells capable of producing having been capped. It is, therefore, not altogether certain what the field will do when opened up, although pumping tests would seem to indicate that there is some very good territory. A pipe-line is now being laid from Sunset into the southern end of the field.

STATISTICS. (December 13, 1903.)

Number of wells producing	24
Number of wells of uncertain value	7
Number of wells drilling	6
Number of wells abandoned	36
Approximate area producing	2 sq. m.
Gravity of oil	Maximum, 22°; Minimum, 14°; Average, 16° Be.
Approximate present price at wells, per barrel	None sold.

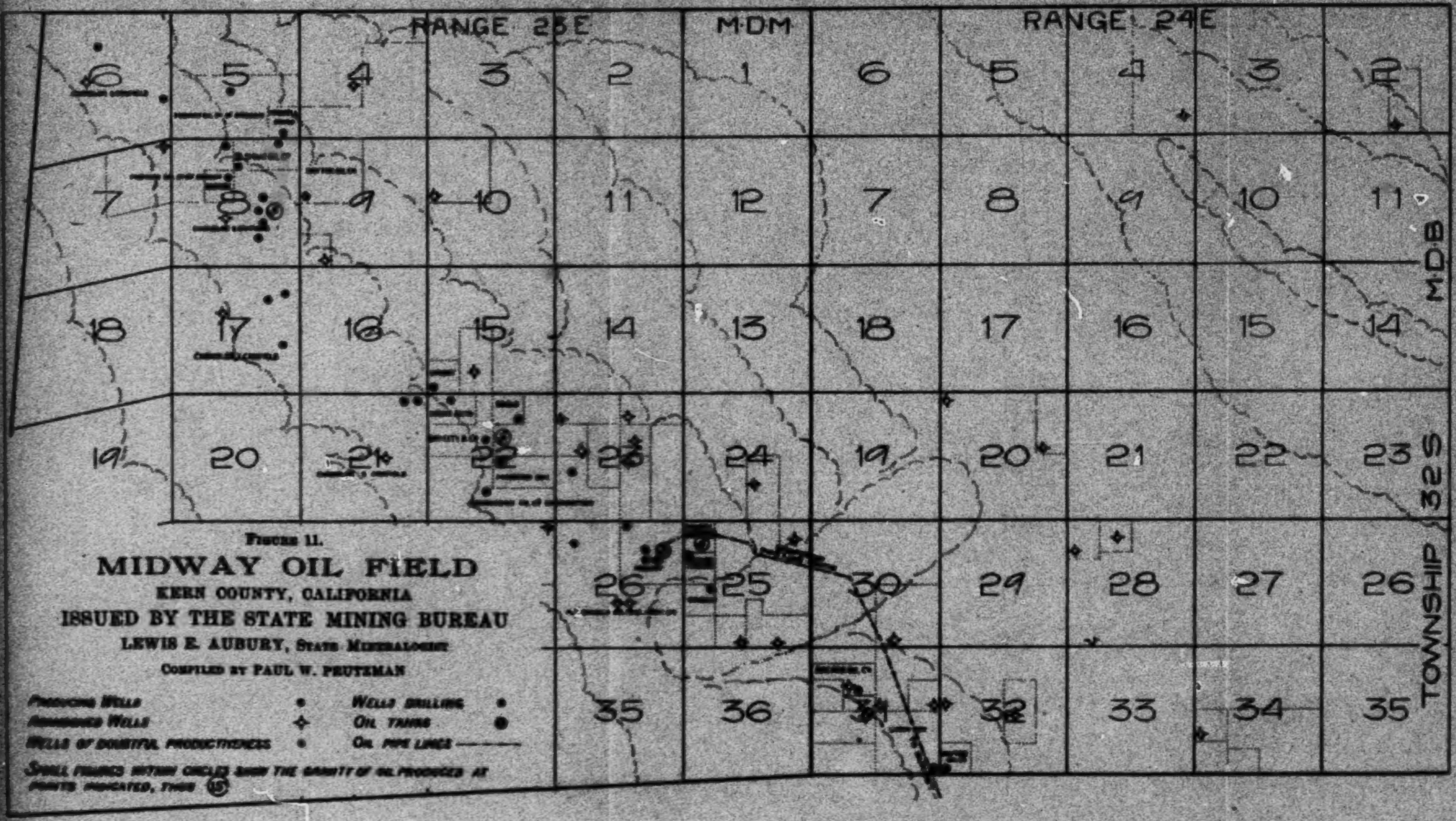
RANGE 23 E
M·D·M
RANGE 24 E
TOWNSHIP 32 S
M·D·B
6 5 4 3 2 1 6 5 4 3 2
7 8 9 10 11 12 7 8 9 10 11
18 17 16 15 14 13 18 17 16 15 14
19 20 21 22 23 24 19 20 21 22 23
26 25 30 29 28 27 26
35 36 31 32 33 34 35
Producing Wells
Abandoned Wells
Wells of doubtful productiveness
Wells drilling
Oil tanks
Oil pipe lines
Small figures within circles show the gravity of oil produced at points indicated, thus 15

Figure 11.

MIDWAY OIL FIELD

KERN COUNTY, CALIFORNIA

ISSUED BY THE STATE MINING BUREAU

LEWIS E. AUBURY, State Mineralogist

Compiled by PAUL W. PRUTZMAN

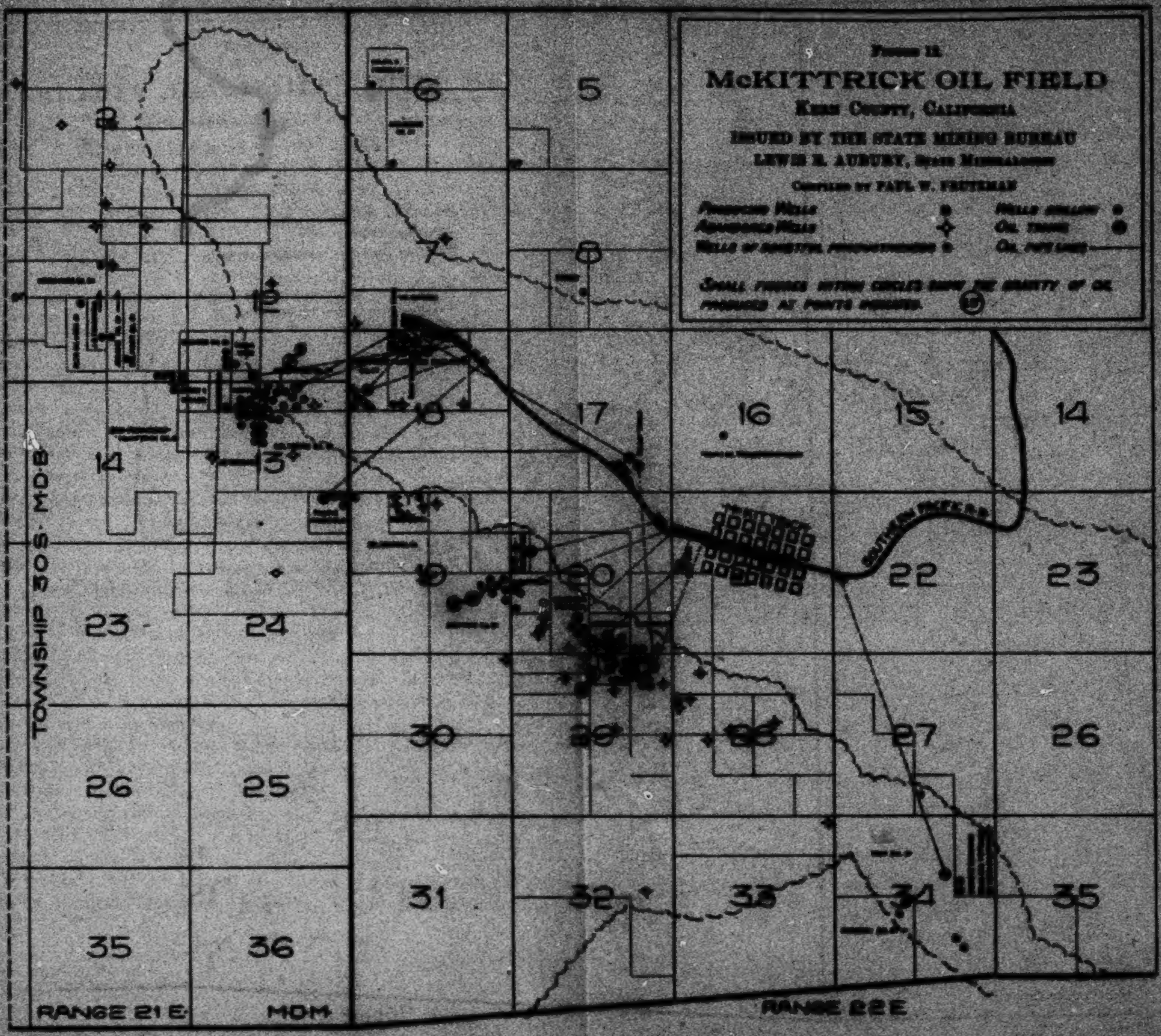
Figure 12.
McKITTRICK OIL FIELD
Kern County, California
ISSUED BY THE STATE MINING BUREAU
LEWIS E. AUBURY, State Mineralogist
Compiled by PAUL W. PRUTZMAN
Producing Wells ●
Abandoned Wells ✦
Wells of doubtful productiveness ●
Wells drilling ●
Oil tanks ●
Oil pipe lines
Small figures within circles show the gravity of oil produced at points indicated.
TOWNSHIP 30 S. M.D.B.
RANGE 21 E.
M.D.M.
RANGE 22 E
McKITTRICK
SOUTHERN PACIFIC R.R.
2
1
6
5
7
8
12
18
17
16
15
14
14
13
19
20
22
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McKITTRICK.

The McKittrick oil field is in the western portion of Kern County, about six miles east of the San Luis Obispo county line, on the east slope of the Coast Range Mountains, and on the west side of the San Joaquin Valley.

The town of McKittrick lies in a flat valley of the width of some two miles, and bounded by hill ranges of no great height, with a due northwest and southeast trend. On the hills to the southwest lie the principal developments, following the line of the valley for three miles. About midway between the town and the head of the valley a group of wells has been drilled in the mesa, while on the south slope of the north hill range some oil has been obtained, though not in paying quantities. The town is at an elevation of 1114 feet, the highest wells 1400 feet.

The formation is of Middle Neocene age, but its shape has not been determined with certainty. It is probable that the parallel hill ranges, which are remarkably regular and persistent, are of anticlinal formation; but such anticlines, if they exist, are certainly much faulted, and the productiveness seems to be largely determined by the presence or absence of these breaks. As will be readily seen, on examination of the map herewith, the field has been thoroughly tested, and proven to be very "spotty," a condition readily explained by the highly broken condition of the surface, and the numerous seepages and evidences of chemical action. Nevertheless, the productive portions of the field have proven highly valuable, on account of the large production per well. Depth of wells varies from 400 or 500 feet to nearly 2000 feet.

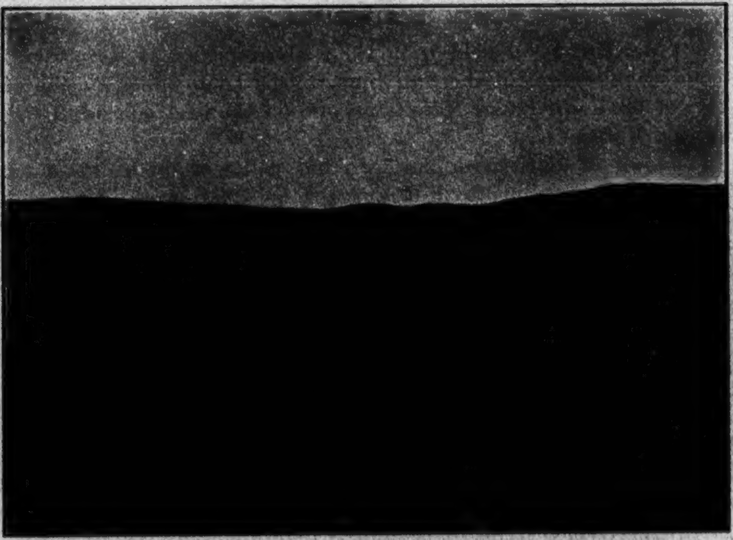
The oils of McKittrick vary in gravity from 14° to 19°, the lighter oil being found entirely at the southern end. In several cases light oil and heavy oil are found in closely adjacent wells, and the variation in gravity in so short a distance is not readily explained. All the oil from this field is used for fuel.

A branch of the Southern Pacific Railroad connects the town of McKittrick with Bakersfield, distant forty-eight miles, and extends two miles farther up the valley, to Olig station. There are numerous pipe-lines connecting various properties with the railroad, and with the Pacific Coast Oil Company and Southern Pacific Company tanks, but no outside pipe-line connection.

The wells on Sections 20 and 29 are pumped on the jack in large part, but north of this line practically everything is pumped on the beam.

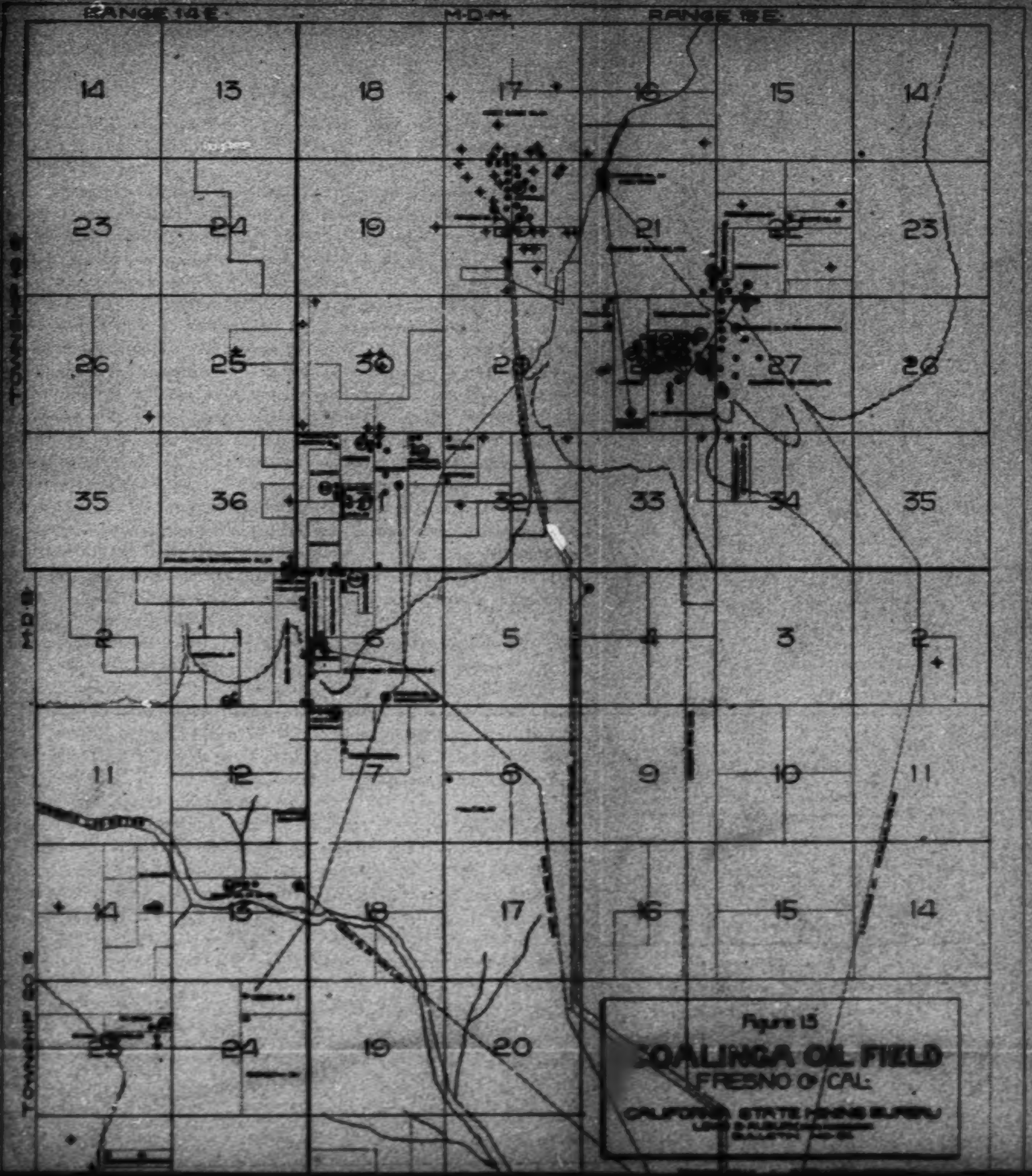
STATISTICS. (December 14, 1903.)

Number of wells producing	75
Number of wells drilling	11
Number of wells not producing	25
Number of wells abandoned	50
Approximate area producing	940 acres.
Gravity of oil	Maximum, 19°; Minimum, 14°; Average, 16° Be.
Approximate present price at wells, per barrel	21 cents.



No. 20. McKittrick—Looking Southeast from Sec. 19, 30 S., 22 E.

No. 21. Coalinga—Oil City Group.


RANGE 14 E.
M.D.M.
RANGE 15 E.
TOWNSHIP 19 S.
M.D.B.
TOWNSHIP 20 S.
14
13
18
17
16
15
14
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24
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Figure 15

COALINGA OIL FIELD
FRESNO CO. CAL.

CALIFORNIA STATE MINING BUREAU
[illegible]
[illegible]

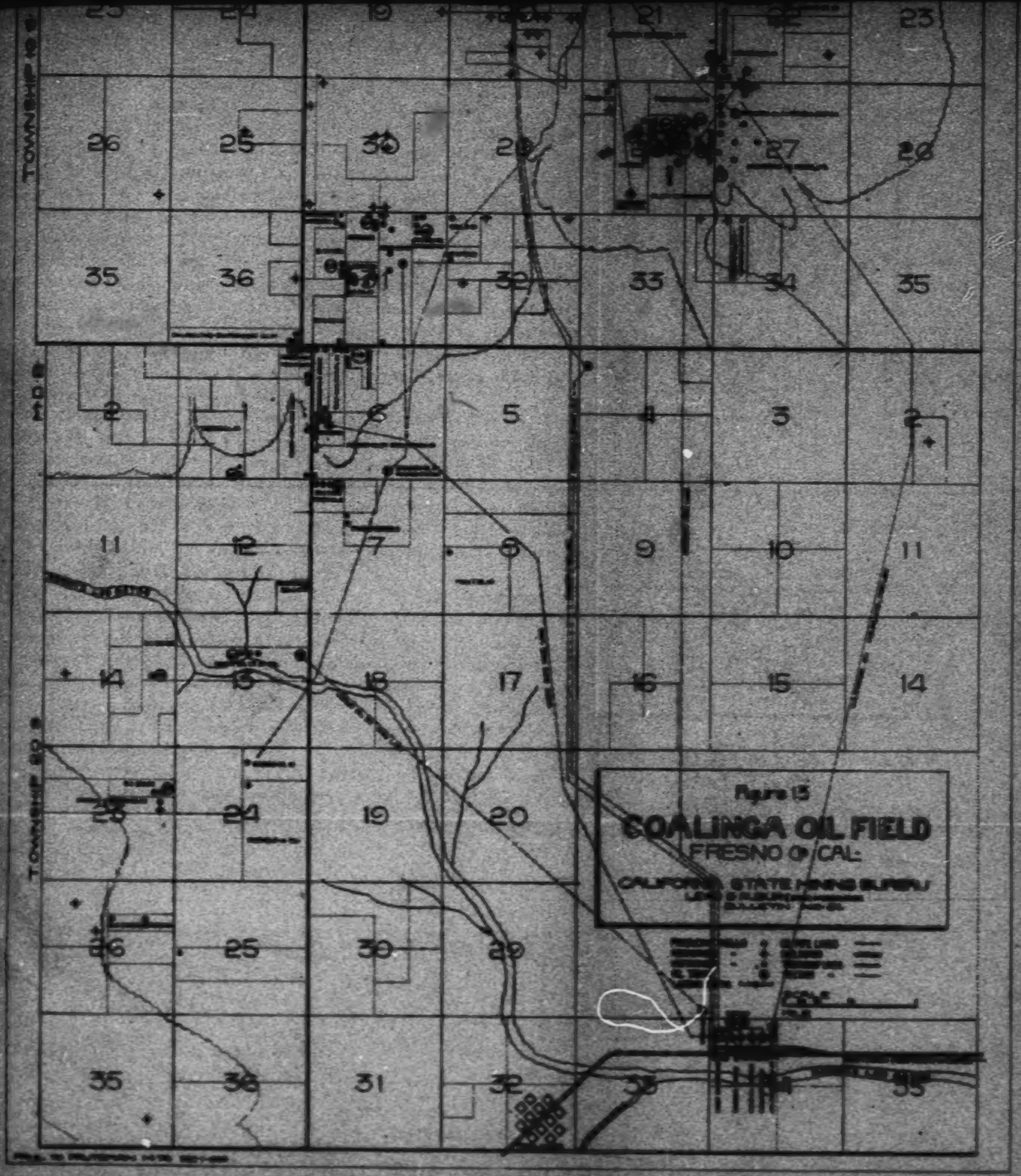


Figure 13

COALINGA OIL FIELD

FRESNO CO. CAL.

CALIFORNIA STATE MINING BUREAU

TOWNSHIP 19 S.
TOWNSHIP 20 S.
23 24 19 20 21 22 23
26 25 30 29 28 27 26
35 36 31 32 33 34 35
2 1 6 5 4 3 2
11 12 7 8 9 10 11
14 13 18 17 16 15 14
23 24 19 20
26 25 30 29
35 36 31 32 33 34 35

COALINGA.

The Coalinga oil field lies at the eastern edge of the foothills of the Coast Range, and on the western boundary of the San Joaquin Valley, in Fresno County.

The village of Coalinga is situated on the mesa, at an elevation of 665 feet; the developed field lies west and north of the town, at a distance ranging from four to eight miles. The hills gradually increase in height and grow rougher toward the north, ranging from 800 or 900 feet at the extreme south, to 1000 feet on Sec. 31, 1200–1400 feet on Secs. 28 and 22, and 1500–1550 feet on Sec. 20, all in T. 19 S., R. 15 E.

The depth of wells varies from 600 feet to over 2000 feet, according to position on dip of producing sand. Two entirely distinct formations furnish oil in this territory. One, following the edge of the hills in a crescent shape, dips gently to the east and southeast, and has been productive over the greater part of the length of the field. This formation is probably of Middle Neocene age, and furnishes black oil from beds of incoherent sand. The productive limits of this formation to the east do not appear to have been reached, but to the west of producing territory the sands outcrop at a number of points, and extension in this direction is improbable. An entirely distinct formation produces oil in the Oil City district, on Sec. 20–19–15, the producing strata being of Eocene age. These strata dip sharply to the southeast, and furnish a green oil from thin layers of sandstone and sandy shale. This pool has been clearly defined on all sides.

The oils produced in the Coalinga field vary greatly in quality. That from the Oil City pool is of a clear green color, and 33° gravity. In the northeast portion of the field, in Secs. 21, 22, and 28, an oil of 26° to 28° gravity is found in the upper sand, and an oil of 20° to 22° below it. On Sec. 31 the oil is from 16° to 18°, growing lighter down the dip of the sand, but falling in gravity as the formation is followed south, to 12° on Sec. 26, and 18° on Sec. 24–20–14. Probably more than half of the oil produced in Coalinga is refined.

The field is served by a branch of the Pacific Coast Oil Company's pipe-line to Point Richmond, which reaches all parts of the field. There are also five pipe-lines from various parts of the field to the railroad at Oro station. A branch of the Southern Pacific Railroad, terminating at Alcalde, connects the town of Coalinga with Goshen, distant fifty-six miles, and through Goshen with Fresno, ninety miles, Bakersfield, one hundred and twenty-nine miles, and San Francisco, two hundred and ninety-six miles.

In the Oil City district, and in the northeastern part of the field, most of the pumping is done by means of jacks, but from Section 31

No. 22. Coalinga—Looking South from S.W. ¼ Sec. 22, 19 S., 15 E.

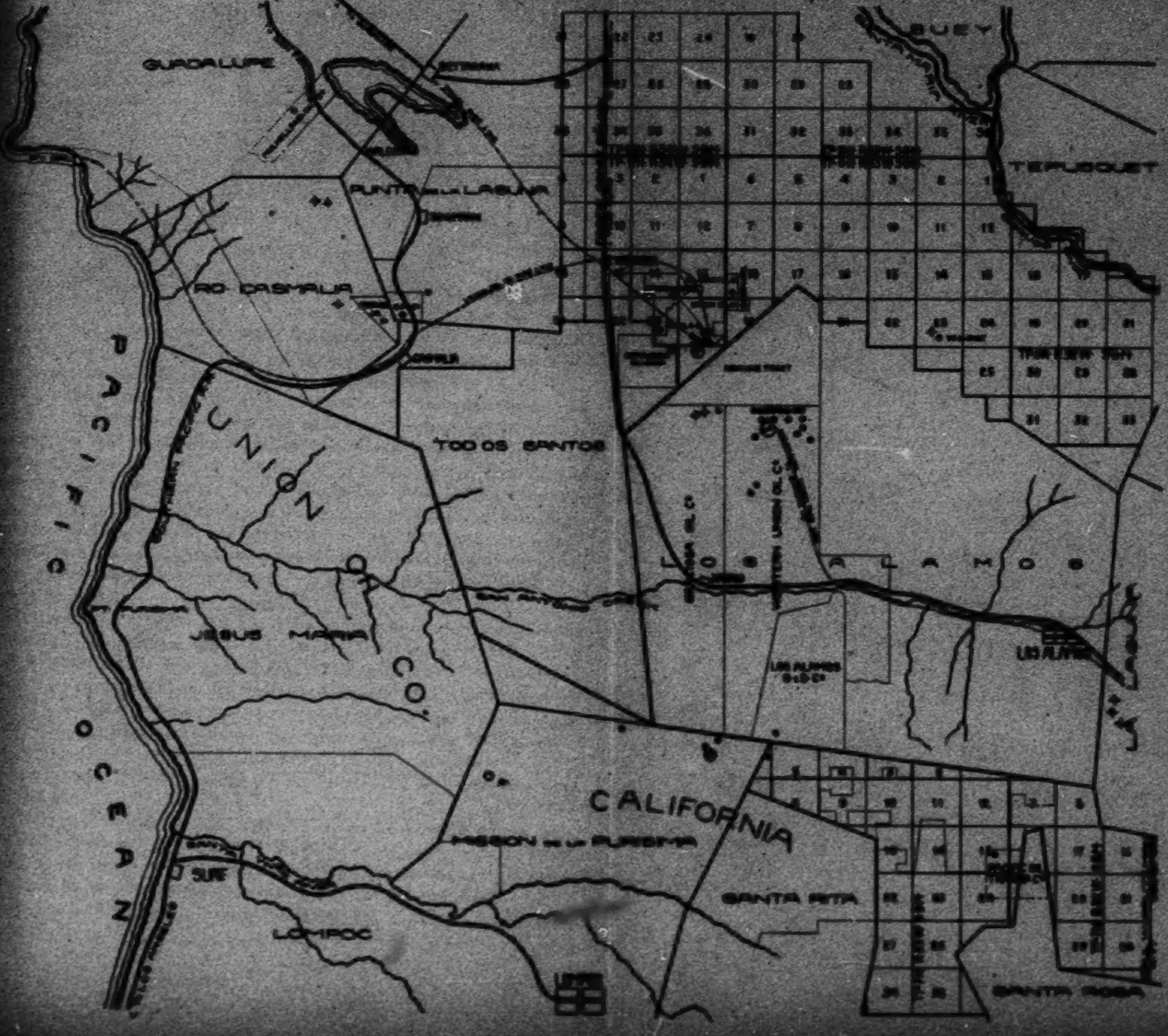
No. 23. Coalinga—Looking North from Section 7.

FIGURE 14.

SANTA MARIA OIL FIELD.

SANTA BARBARA COUNTY, CAL.

Issued by the State Mining Bureau. Lewis E. Aubury, State Mineralogist.


GUADALUPE
PUNTA DE LA LAGUNA
SUEY
TEPUSQUET
RO. CASMALIA
PACIFIC OCEAN
UNION OIL CO.
TODOS SANTOS
LOS ALAMOS
SAN ANTONIO CREEK
JESUS MARIA
CALIFORNIA
MISSION DE LA PURISIMA
SANTA RITA
SANTA ROSA
SURF
LOMPOC

south the wells all pump on the beam. There are three or four wells in this part of the field which flow quite freely.

STATISTICS. (December 1, 1908.)

Number of wells producing	110
Number of wells drilling	33
Number of wells not producing	6
Number of wells abandoned	63
Approximate area producing	2400 acres.
Gravity of oil	Maximum, 33.3°; Minimum, 11.8°; Average, 20° Be.
Approximate present price at wells, per barrel—	
20° and heavier	20 cents.
23°	25 cents.
27°	60 cents.
28°	80 cents.

SANTA MARIA.

The oil fields of northern Santa Barbara County, which for lack of a settled title have been noted here under this name, are yet too new to warrant any detailed description. A small number of wells are scattered over a very large area, and the intervening territory, while very hopeful, is yet an unknown quantity.

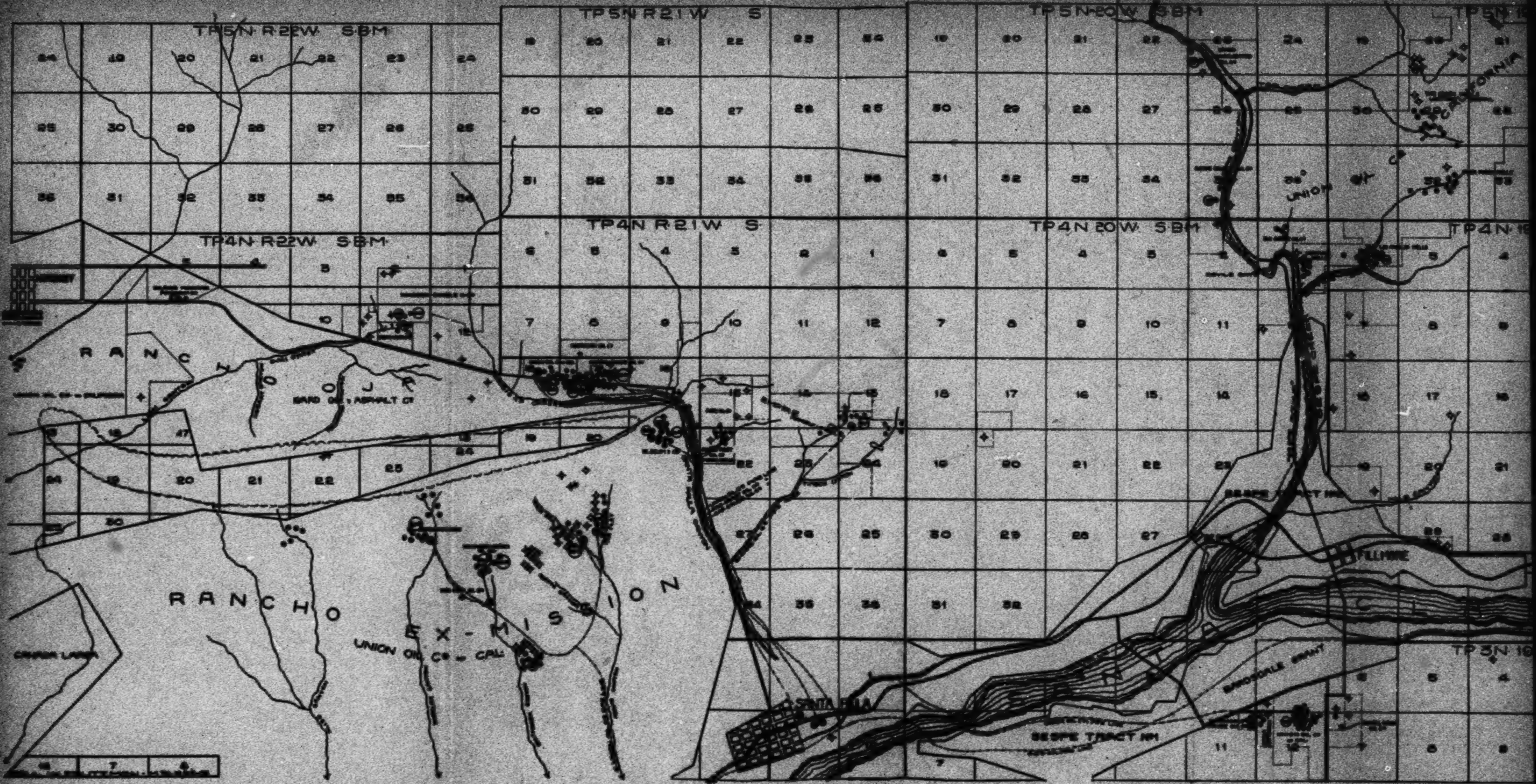
This district slopes gradually to the shores of the Pacific Ocean, and is a country of parallel, low hill ranges, separating narrow valleys parallel to and south of the valley of the Santa Maria River. The more elevated portions of the district are suitable for grazing; the valleys are fertile farming land. The larger part of the area was covered by a Spanish colony of early date, and divided into large ranches, and the oil holdings are largely on mineral leases. As will be seen from attached map, most of the holdings are large, and the entire area which now appears promising is concentrated in the hands of a few large firms.

The towns of Lompoc and Los Alamos are within the limits of the field, while the thriving little city of Santa Maria lies but a mile to the north of the north line of the map. The coast line of the Southern Pacific Railroad lies along the western edge of the field, which is crossed also by the Pacific Coast Railway, a narrow-gauge line running from Los Olivos to San Luis Obispo via Santa Maria. The latter town is two hundred and fifty-three miles from San Francisco, while Casmalia on the Southern Pacific is distant one hundred and ninety miles from Los Angeles.

The pipe-line facilities are, as would be expected in so new a field, rather incomplete. A line extends from the Pinal property in the north to the sugar factory at Betteravia; another from the same initial point to Graciosa on the Pacific Coast Railway, this line being surveyed to Point Sal landing, on the ocean. A third line connects the Western

No. 24. SANTA MARIA FIELD, SANTA BARBARA CO.—CARREAGA WELLS.

No. 25. A TYPICAL OIL RESERVOIR.


TP5N R22W S.B.M.
TP5N R21W S
TP5N 20W S.B.M.
TP5N 19
TP4N R22W S.B.M.
TP4N R21W S
TP4N 20W S.B.M.
TP4N 19
TP3N 19
RANCHO OJAI
BARD OIL & ASPHALT CO
UNION OIL CO OF CAL
CALIFORNIA
RANCHO EX-MISION
UNION OIL Co of CAL
CANADA LARGA
SANTA PAULA
FILLMORE
SESPE TRACT No1
BARDSDALE GRANT

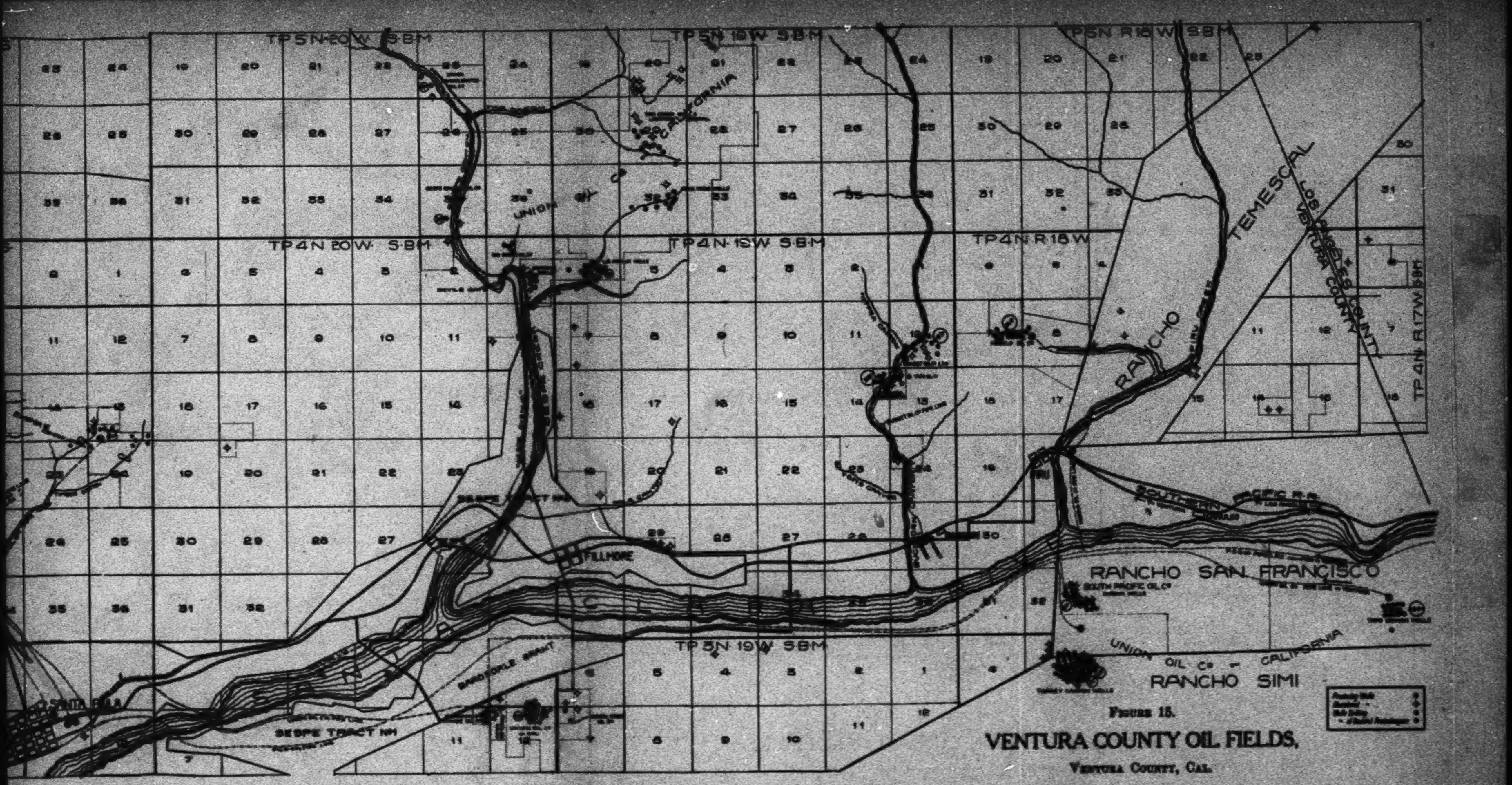

TP 5 N 20 W S.B.M
TP 5 N 19 W S.B.M
TP 5 N R 18 W S.B.M
TP 4 N 20 W S.B.M
TP 4 N 19 W S.B.M
TP 4 N R 18 W
TP 4 N R 17 W S.B.M
TP 3 N 19 W S.B.M
UNION OIL Co CALIFORNIA
RANCHO TEMESCAL
LOS ANGELES COUNTY
VENTURA COUNTY
SOUTHERN PACIFIC R.R.
FILLMORE
SANTA PAULA
SESPE TRACT No
RANCHO SAN FRANCISCO
SOUTH PACIFIC OIL Co
UNION OIL Co — CALIFORNIA
RANCHO SIMI

FIGURE 15.

VENTURA COUNTY OIL FIELDS.

VENTURA COUNTY, CAL.

Union property with the oil refinery at Gaviota, on the ocean. The southern portion of the field has as yet no outlet.

The larger part of the oil from this field is used for refining purposes.

STATISTICS. (December 20, 1903.)

Number of wells producing	21
Number of wells drilling	18
Number of wells of uncertain value	2
Number of wells abandoned	10
Approximate area producing	2000 acres.
Gravity of oil	Maximum, 27°; Minimum, 16°; Average, 20° Be.
Approximate present price at wells, per barrel	up to 80 cents.

VENTURA COUNTY.

The coast line of Ventura County lies roughly east and west, and is paralleled by a range of steep hills. North of these hills, and therefore also parallel with the coast, lies the valley of the Santa Clara River, a small stream which takes its rise in the San Fernando Mountains, and enters the ocean at Ventura. The oil deposits of this region have been found along both sides of the Santa Clara, the larger area of producing territory being to the north.

The river valley is here some two miles wide, is fertile, and completely farmed, supporting the small towns of Camulos, Piru, and Fillmore, and the little city of Santa Paula. The hills to the south and north of the valley are steep, rough, and entirely barren, those to the south being of moderate height, being some 2000 feet in general above the valley floor, which is itself at this point some 600 feet above sea level.

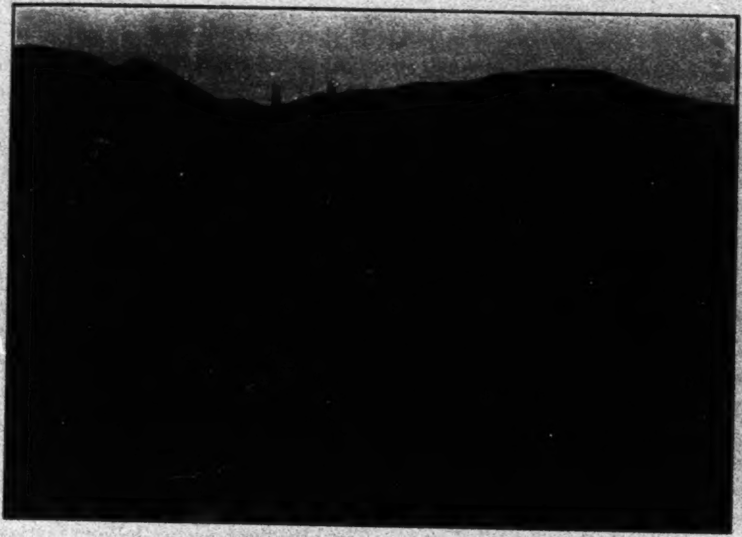
The San Rafael Mountains, to the north of the valley, rise abruptly to a considerable height, not less than 4000 feet at some points. The wells to the south of the river are mostly well down the slope of the hills, some practically at river level, while those on the northern slope commence at an elevation of some 1200 feet, and rise to a maximum height of 2800 feet above sea level. Owing to the fact that these wells to the north are largely situated in cañons among very rough hills, many of the leases are accessible only with difficulty.

The major part of the production comes from the wells south of the river, and from those on Mount Cayetano to the east and Sulphur Mountain to the west of Santa Paula Cañon. Many of these wells are quite old, and a number have been pumped out and abandoned, though in general the entire territory has been characterized by great stability. As would be expected in such broken ground, the producing areas are small and somewhat scattered. In general, the producing formation seems to be lenticular, so far as productiveness is concerned, rich at the center and rapidly failing at distance, either from disappearance of the sand or from progressive lowering of its saturation. This spottiness, combined with the difficulties offered by the surface, have made prospecting very expensive and uncertain; but as the oil is largely of a high grade, and production per well satisfactory and lasting, successful wells have been very profitable to their owners.

The coast line of the Southern Pacific Railroad extends through the Santa Clara Valley, distances from Santa Paula being, to Los Angeles sixty-five miles, to San Francisco four hundred and sixteen miles. The Pacific Coast Oil Company has a trunk pipe-line through the valley from Pico Cañon in Los Angeles County to Ventura; the Union Oil Company a line from Tapo Cañon, south of Camulos, to the same point. There are also three lines to the railroad from various points, and numerous branches connecting the trunk lines to various parts of the field. The larger part of the production goes from Ventura by water to San Francisco, and is there refined.

STATISTICS. (December 20, 1903.)

Number of wells producing	30
Number of wells drilling	11
Number of wells of uncertain value	2
Number of wells abandoned	14
Approximate area producing	7 sq. m.
Gravity of oil	Maximum, 40°; Minimum, 14°; Average, 24° Be.
Approximate present price at wells, per barrel	40c to $1.5



No. 26. Ventura—Wheeler Cañon Wells, Burrows & Son.

No. 27. Ventura—Torrey Cañon Wells, Union Oil Co.

PART II.

USES OF CRUDE OIL.

CHAPTER 4.

PHYSICAL CHARACTERISTICS OF CALIFORNIA CRUDE.

Color.—The color of California crude petroleum ranges from a deep brownish black to water white, the usual color being black or dark brown. This dark color is due to the asphalt, and changes to green of more or less brilliancy on removal of this substance; a few of the oils containing little or no asphalt are green in their crude state, while even some of the lighter asphaltic oils show a green tinge. The fluorescence of the crude oils is uniformly green, and not very pronounced; the bloom on refined oils follows the usual rule, *i. e.*, is absent in the naphthas, blue in the kerosenes and lighter lubricating oils, changing to green in the heavier lubricants. The blue fluorescence follows farther down the scale of lubricants than with the usual oil of the Eastern States, and the bloom on all products, both light and heavy, is less pronounced.

Odor.—The odor of the heavier oils is highly characteristic, but mild and rather sweet, very rarely sulphurous. The foul odor of the oils of Texas, Canada, and Ohio is entirely absent. Many of the lighter oils are sweet, resembling Pennsylvania crude in this respect. In brief, the odor is very seldom objectionable.

Specific Gravity.—The specific gravity ranges from 1.025 (3° on Beaumé's heavy scale) to 0.7490 (58° Beaumé), but most of the production falls within the range between 13° and 35° Be. The production of the entire State would average about 16.5°.

It will be noted that the specific gravity is very low. This is partly due to the fact that a large part of the petroleum of this State is highly oxidized and quite viscous. But it is also a fact that the lighter oils are also of quite low gravity (by comparison), being from 10° to 15° Be. lower than would be indicated by the viscosity and boiling range. The very low gravity appears to indicate a radical difference of constitution from that of the paraffin oils, a subject which will be treated more in detail in later paragraphs.

Viscosity.—The viscosity of California petroleum ranges from that of a semi-solid substance to less than 1.00 (the viscosity of water). The average viscosities are: for oils of 14° gravity, 1000; for oils of 16° gravity, 400; for oils of 18° gravity, 75; for oils of 20° gravity, 15. Different samples of the same gravity vary considerably in viscosity. These and following viscosities (excepting those in Table 4*a*) are taken by Engler instrument at 60° F., water at the same temperature being taken as 1.00.

The high viscosity of the heavier California oils is a very important factor in handling them on a large scale. The oils lighter than 20° are piped cold without difficulty, flowing freely under a moderate head. Some oils of 18° gravity, even, may be piped readily, but the handling of the heavier oils through lines of any length is a matter of some difficulty, and requires special precautions.

The viscosity as read in the laboratory, though compared directly with that of water, can not be considered an absolute measure of the resistance to pumping, as compared with the resistance of water under the same conditions. The laboratory viscosity determination is made, as a rule, through a very small orifice, highly polished, and rather short, and it will be evident that capillarity and the surface tension of the oil cut a considerable figure in determining the speed of discharge, while in piping the oil the interior or fluid friction is the main source of resistance to flow, that portion of the oil in actual contact with the walls of the pipe being practically immovable. Nevertheless, the laboratory determination of viscosity is, in the absence of more practical data, a valuable indication as to the real fluidity of the oil, particularly if determinations are made at various temperatures and the results plotted.

The viscosity of our 14° to 16° oil falls very rapidly with increasing temperature, the viscosity at 110° F. being, as a rule, from one eighth to one tenth of the viscosity at 60° F.; that is to say, an oil which reads 300 at 60° would generally read from 30 to 40 at 110° F. Above this temperature the decrease is much less rapid. This decrease in viscosity with rising temperature offers a means of rendering the oil sufficiently fluid to pipe, and this method is the one generally used on short lines. The oil is heated in the tank, by means of steam coils, to such temperature as is needed to render it sufficiently fluid, and enough in excess to offset the loss of heat from the line. The only drawback to this method of working is that it is limited in its application to the distance to which oil originally heated to 200° (which is the highest temperature practicable) may be pumped without falling much below 100°. This distance varies with the conditions, temperature of surrounding soil, size of line, and proportion of time in use, but it would probably be conservative to set five or six miles as the greatest distance to which oil can be pumped hot, under ordinary conditions, at all seasons of the year. Even at this distance, unless special precautions are taken to retain the heat, much difficulty is experienced.

Pipe-Lines.—In the Kern River oil field there are a number of lines which carry oil from various parts of the field to the railroad. These lines range in length from a few hundred feet to about four miles, and in diameter from 4″ to 7⅝″. On one line in the southeastern part of the field, the following results have been noted:

Diameter of pipe	5$\frac{11}{16}$ inches.
Length	5600 feet.
Course	Straight; fall about 100 feet, with very little undulation.
Gravity of oil	13.8° Be.
Initial temperature	140° F.
Initial pressure	250 to 300 pounds.
Maximum discharge	600 barrels per hour.
Minimum discharge	25 barrels per hour.

The maximum discharge was noted during hot weather (the temperature of the air at this point often reaches 120° F.) and after the line had been cleaned and heated by continued use. The lower figure was the average of a twelve hours' run during the winter, the line having been shut down for some time previous. This line is buried approximately twelve inches.

On another line in the same general neighborhood, the following results were obtained:

Diameter of pipe	6 inches.
Length of line	5000 feet.
Course	Straight, very little difference of level between terminals, some slight undulations.
Gravity of oil	15.5° Be. average.
Initial temperature	80° to 100° F.
Initial pressure	250 to 450 pounds.
Maximum discharge	1100 barrels per hour.
Minimum discharge	330 barrels per hour.

These figures for discharge are the averages of the times required to discharge a 20,000-barrel tank, the maximum being in summer, when the surface of the ground is at least as hot as the oil, the minimum in winter, when the temperature of the air is about 60° F. on an average. This line is practically on the surface.

A line was laid, not long since, from the Kern River field to a point not far from San Francisco, a distance of two hundred and seventy-eight miles. This line is eight inches in diameter, laid about three feet beneath the surface, and very carefully wrapped in asphalted paper, to exclude dampness and retain heat. The line was divided into ten blocks, of approximately equal length, each block being an independent line, with its own pumps, heaters, and receiving tanks. The oil was heated to 180° F., and pumped under six hundred pounds pressure. Details as to the results of this interesting experiment are not available, but it is known that much difficulty was experienced, and that the carrying capacity was small. It is not now in operation (April, 1904), although it is reported that work will be resumed during the summer. The entire course of the line is in the San Joaquin Valley, through a sandy soil, temperatures during the summer ranging about 110° at noon and 70° at midnight, and in winter down to 50° F.

Another, and more widely applicable, method is to pump water into the line with the oil. The disadvantages of this system are obvious:

that the water is valuable at many points where oil is produced, and that water, once mixed with a heavy oil, is not readily separated. There is the great advantage, however, that the system will work to a much greater distance than the other, and further that the rate of discharge varies little with fluctuations of temperature.

The theory of the system is that the oil, from its great cohesion and high surface tension, will form a solid core, surrounded and kept from contact with the pipe by a layer of water, the core rotating slowly as it passes through the pipe. Theoretically the friction is that of water in pipes, but practically it is greater, as the layer of water can not be kept intact over the entire surface, and wherever the oil lays hold of the pipe the resistance to flow is increased.

The essential factor in this process is to keep oil and water separate, as far as possible, in the pipe, as an emulsion of oil and water is often less fluid than the oil itself. The water should be introduced after the oil, from a separate source of supply, and in such manner as will tend not to mix the two, but to retain the water next to the walls of the pipe. In order to keep the oil from breaking through the water layer, any obstruction or enlargement which would cause an eddy is carefully avoided, bends are made of long radius, and the level is preserved as far as possible. Where care has been taken as to these points the system has worked admirably in a number of situations, and has made it possible to pipe oil from remote situations where the pumping of hot oil would be impracticable. Arrangements have, of course, to be provided for separating water from oil at terminus.

A line worked on this principle runs from the Buckhorn wells in Ventura County to the railroad at Buckhorn. Mr. W. L. Watts (Bulletin 19, California State Mining Bureau) reports as follows regarding this line:

Diameter of line	2 inches.
Length of line	5 miles.
Course	Sinuous, long bends, no great undulations.
Temperature	75° in summer, 60° in winter.
Pressure	500 feet head.
Maximum discharge	21 barrels oil per hour, in summer.
Minimum discharge	15 barrels oil per hour, in winter.

Flash Point.—The flash point of California crude ranges from 400° F. down to 60° F. or lower. Most of the oil classed as fuel oil flashes above 150° F., and practically all of it above 130° F. It will be seen that none of the fuel oil of this State requires any preparation, in regard to flash point, to fit it for use. Considerable quantities of prepared oil for fuel are now being put on the market, these oils being the residues of the distillation of lighter oils, and similar to the "astatki" of the Caucasus. These oils are of high flash point, and are of excellent quality in all respects.

All the flash points mentioned herein, with the exception of those in Table 4*a*, are by the open electric cup, standard in San Francisco.

Calorific Value.—The calorific value of California crude ranges from 10,000 to 11,000 calories (18,000 to 19,800 B. T. U.), and averages 10,500 calories (18,900 B. T. U.). As a rule, the higher the gravity of the oil, the higher the calorific value, though this generality can not be applied too closely.

This average of 10,500 calories is 1.8% lower than the average of six Pennsylvania and West Virginia petroleums (Poole, "Calorific Power of Fuels," p. 251), and 1.1% lower than the average of six samples of Beaumont (Texas) oil (from various sources). Taking account, however, of the difference in weight per unit of volume, the specific gravity of the Pennsylvania oils being 0.8490, of the Texas oils 0.9200, and of the California oils 0.9415, the figures would stand: California 1.000, Texas 0.988, Pennsylvania 0.918. The advantage would be slightly with the California oil, although the number of determinations is really too small to be the basis for a general deduction.

In Table 4, following, will be found gravities, viscosities, flash and burning points, and calorific values of a number of samples of California crude oil. The figures in the first portion of the table are from a paper by Prof. Edmund O'Neill, of the University of California, published in the "Journal of the American Chemical Society," July, 1903. The figures in the second portion of the table were made by Mr. Wayne Colver and by the writer, in the latter's laboratory. A large number of determinations of physical properties will be found in the last table in this volume, these figures being by Mr. H. N. Cooper.

TABLE 4. PHYSICAL CHARACTERISTICS OF CALIFORNIA CRUDE OILS.

(A) *By Prof. Edmund O'Neill, of the University of California.*

No.	Field.	County.	Color.	Gravity at 60° F., in degrees Beaumé	Flash. (Degrees Fahrenheit)	Burn. (Degrees Fahrenheit) ...	Viscosity at		Calorific Values, in Calories ...
							60° F.	180° F.	
145	Colusa	Colusa	....	14.3°	....	....	4.88	1.28	18,648
100	Napa	Napa	Brown	15.5	208°	280°	10.35	1.34	....
161	Humboldt	Humboldt	Red-Brn. .	29.0	....	....	1.57	1.05	....
101	Humboldt	Humboldt	Yellow....	37.5	b. 50	b. 50	1.10	0.95	....
95	Humboldt	Humboldt	Yellow....	26.1	228	237	3.00	1.15	....
99	Humboldt	Humboldt	Yellow....	48.6	63	65	1.17	0.96	....
159	Santa Clara....	Santa Clara....	....	34.4	....	....	....	....	20,146
184	San Mateo	San Mateo	Brown	22.1	194	215	10.96	1.50	....
160	Coalinga........	Fresno........	Brown	20.3	158	202	11.19	1.54	....
134	McKittrick	Kern	....	17.7	....	....	63.15	2.12	18,675
135	McKittrick	Kern........	Black	15.1	....	....	282.08	3.57	18,571
103	Sunset	Kern........	Black	16.0	....	....	....	....	18,064
110	Kern River	Kern........	....	13.4	....	....	....	....	18,473
111	Kern River	Kern........	Black	13.2	....	....	1759.13	7.51	18,342
112	Kern River	Kern........	Black	14.7	....	....	274.35	3.35	18,848
156	Kern River	Kern........	Black	16.0	....	....	373.11	3.67	18,646
157	Kern River	Kern........	Black	16.3	....	....	289.59	4.70	18,797
113	....	....	....	17.0	....	....	142.68	2.85	18,630
187	....	....	....	14.7	196	221	347.77	3.37	....
129	....	....	....	28.0	....	....	....	....	19,440
149	Summerland..	Santa Barbara	Black	12.1	....	....	1462.83	8.35	....
186	Ventura	Ventura	....	23.0	84	95	34.28	1.84	....

TABLE 4. PHYSICAL CHARACTERISTICS OF CALIFORNIA CRUDE OILS—Cont'd.

(B) *By Wayne Colver and Paul W. Prutzman.*

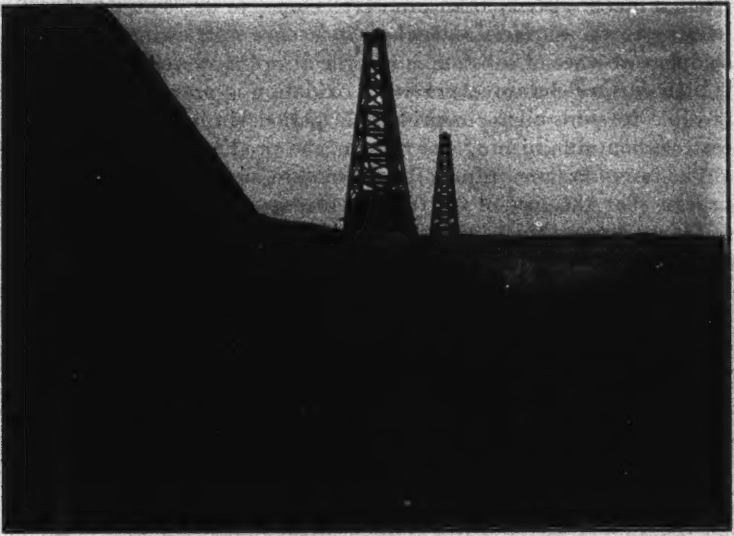
No.	Field.	County.	Color.	Gravity at 60° Fahrenheit	Flash. (Degrees Fahrenheit)	Burn. (Degrees Fahrenheit)	Viscosity.	
							Reading.	At Degs. Fah.
405	Los Angeles City	Los Angeles	Black	15.2°			63.40	72°
2413	Los Angeles City	Los Angeles	Black	13.5	258°		730.44	76
2495	Los Angeles City	Los Angeles	Brown	13.0	260	343°	1004.35	60
2494	Ojai	Ventura	Black	11.8	270	310	1728.33	60
2425	Ex-Mission	Ventura	Green-Black	25.4	120	139	6.96	65
2442	Bardsdale	Ventura	Brown	28.0	b. 60		13.56	60
2492	Fullerton	Orange	Brown-Black	20.2	120	192	28.70	61
2493	Fullerton	Orange	Brown-Black	20.6	140	196	62.61	62
2441	Fullerton	Orange	Brown	33.0	b. 60	b. 60	2.82	50
1463	Whittier	Los Angeles	Black	19.0	108		32.80	62
2491	Whittier	Los Angeles	Black	20.4	154	228	256.26	61
2451	Whittier	Los Angeles	Black	21.0	127	180	35.20	60
2426	Puente	Los Angeles	Brown-Black	20.1	60	98	4.22	70
2421	Puente	Los Angeles	Brown	27.2	78	120	7.30	70
2454	Newhall	Los Angeles	Black	14.0	263	280	782.60	64
1419	Newhall	Los Angeles	White	42.7	b. 60	b. 60	0.92	70
2412	Santa Maria	Santa Barbara	Black	16.9	130		156.00	68
498	Bitterwater	San Benito	Brown-Green	42.7	b. 60	b. 60	1.29	70
433	Panoche	Fresno	Brown	32.9			3.02	61
430	San Mateo	San Mateo	Greenish	41.7	b. 60		1.08	60
1465	San Mateo	San Mateo	Brown-Green	48.8	b. 60	b. 60	1.10	61
444	Colusa	Colusa	Green	15.2	252	300	3.74	72
434	Napa	Napa	Green-Brown	15.2			6.97	58
497	Bolinas Bay	Marin	Brown-Black	21.5	133	182	46.52	62
2490	Coalinga	Fresno	Brown-Black	28.5	60	68	3.06	61
1450	Coalinga	Fresno	Black	21.9	149	187	8.40	64
1466	Coalinga	Fresno	Black-Brown	19.8	143	178	29.20	60
1496	Coalinga	Fresno	Black	16.8	248		158.00	60
1493	Coalinga	Fresno	Black	12.6	322			
2405	Coalinga	Fresno	Black	11.9			1513.00	75
1454	Sunset	Kern	Black	9.9	308			
1480	Sunset	Kern	Black	14.4	290		716.00	75
1471	Sunset	Kern	Black	16.5	210			
2435	Midway	Kern	Black	13.0	296	368	1565.22	65
1482	Midway	Kern	Black-Brown	20.2	162		26.50	68
1499	McKittrick	Kern	Black	11.9	304	354	Semi-solid	60
2443	McKittrick	Kern	Brown	13.6	275	317	866.00	60
2444	McKittrick	Kern	Black	15.1	267	313	338.30	66
1490	McKittrick	Kern	Brown-Black	19.0	178	194	21.90	65
1470	Kern River	Kern	Black	10.4	348		Semi-solid	60
1462	Kern River	Kern	Black	13.9	269		249.50	75
1489	Kern River	Kern	Black	15.6	253	282	341.70	60

Cleaning Crude Oil.—The lighter of the crude oils of California, being found, as a rule, in coherent formations, are obtained in a clean condition, any water or fine sand which may be pumped with the oil settling out readily. But most of the heavy oils are found in loose sand, often of great fineness, and where the gravity of the crude falls below 18° a large amount of sand will be pumped with the oil. This sand, and the accompanying water, must be removed by long standing, or by the application of heat, or by both.

In the Kern River field, where the greatest difficulties with sand are experienced, and where the most ingenuity has been exercised in providing against these difficulties, it is customary to pump into settling holes or sumps, these being simply excavations in the sandy soil, of small size, and placed as close to the well as convenient. From these sumps, which are originally of from 500 to 2000 barrels capacity, but which rapidly grow shallower from the deposition of detritus from the oil, the latter flows by gravity to the storage reservoirs. These reservoirs are large shallow excavations, formed in general in the following manner: A rectangle of convenient size is laid off, and an embankment formed about it by plowing and scraping. The ground is thoroughly wet down, both before plowing and on the embankment after the scraper is dumped. In this manner the hoofs of the horses drawing scrapers operate to thoroughly consolidate and tamp down the wet earth, and a very close bank is formed without any further treatment. The embankment being brought to the desired height, and the bottom of the tank brought to grade, the reservoir is finished, except for a light roof of wood, covered with tarred felt or asphalt roofing. The oil is drawn off below through a pipe set in the bottom of the tank, and arrangements are also provided for drawing off any accumulation of water.

These reservoirs are often of great size, and it is customary to carry in them as large a stock as possible, in order that the oil may stand quietly for some time, to settle thoroughly. During the summer months the oil stands continually at a high temperature, in spite of being roofed over, and becomes quite clean without further treatment. During cooler weather, or in any case where reservoir purification is not thought to be sufficient, the oil before shipment is passed through a cleaning tank, generally a small steel tank, provided with steam coils, and with two outlets. Here the oil is heated to from 110° to 150°, according to gravity and to degree of impurity, and the purification is completed in the course of a few hours. The high degree of purity which is attained by the use of these simple methods is quite astonishing. Even where the impurities originally amount to fifty per cent of the bulk of the crude oil, which is often the case, the oil finally shipped will not contain more than two per cent of foreign matter of all kinds, and the larger part of the fuel oil found in the San Francisco market, at least, will be found to contain less than one and one half per cent of impurity.

Where large surfaces of heavy crude oil are exposed to sunlight, in the hot climate incident to most of our oil fields, oxidation takes place, and the gravity of the oil is rapidly lowered, while the viscosity is increased. If this operation is allowed to go on too long, the oil will be reduced to a tarry condition, and its commercial value destroyed. If sunlight be excluded, however, the effects of a high temperature are not very noticeable, once the fixed gas is eliminated from the oil. Heavy crude oil, as it comes from the well, contains considerable permanent gas, intimately mixed with the oil, and the latter thus shows, when



No. 28. Empty Oil Reservoir, McKittrick, Cal., Associated Oil Co.

No. 29. Oil Reservoir, McKittrick, Cal., Pacific Crude Oil Co.

fresh, a higher gravity than properly belongs to it. This gas soon finds its way to the surface, and when it is once out, owing to an almost complete absence of substances volatile at ordinary temperatures, there is little further change in gravity if oxidation is prevented. It is thus possible to store oil for considerable periods in reservoirs of very low cost, without diminishing the value of the product.

The reservoirs are ordinarily not lined in any way, as experience has proven that the loss of oil through seepage is very small. While the soil is, as a usual thing, light and sandy, the finer particles of sand from the oil rapidly fill the pores in the earth, and the water from the oil makes this coating quite impervious to the passage of oil. The cleaning up of a large number of tanks in the Kern River field has shown that, even where oil has stood in a reservoir for months, the penetration into the soil was rarely greater than four inches.

CHAPTER 5.

THE USE OF OIL FOR FUEL.

The advantages attending the use of oil for fuel have been so often dwelt on, and have come to be so generally appreciated, that it may seem useless to go over them at this time. Nevertheless, some are yet unconvinced, and even to those who are using liquid fuel it may be a matter of interest to recall the various ways in which petroleum excels solid fuel.

Transportation.—The first advantage is ease of transportation. This may not amount to much to those who have their fuel delivered at their doors, but in situations where fuel must be transported as used, notably on steamships, it is a very important matter. The loading of a steamship with coal requires days where an equivalent quantity of oil may be loaded in as many hours, and entirely without labor. By modern devices oil may be pumped into or out of vessels at points where it would be impossible to dock and discharge or take on a cargo of coal, while vessels at sea may transfer supplies of oil in weather which would quite prevent transferring of coal. The fuel tanks of oil-burning locomotives are loaded with the turn of a valve, and in a minimum of time, while tank wagons deliver oil to stationary plants where the handling of coal would create a nuisance, from the dust raised, as well as seriously depreciate the value of the solid fuel.

Storage Space.—Where a supply of fuel must be stored, a second advantage in the use of liquid fuel is shown. If we assume as a basis that four barrels of oil are equal in fuel value to one ton (2240 lbs.) of good bituminous coal, the oil occupies a space less than three fourths as great as would be required for the coal;—to be more accurate, the four barrels of oil would occupy a space of 22.5 cubic feet, the ton of coal from 32 to 38 cubic feet, making the space required for the oil from 59% to 70% of that taken by the coal. Furthermore, no matter how limited boiler-room space may be (and in office buildings, etc., this space often represents considerable value), the working supply of coal must always be on the boiler-room floor, while the oil supply may be, and in such cases generally is, buried under the sidewalk or the cellar floor, thus taking no space whatever which would be of any value for other purposes, beyond that required for the manhole and the connections.

Cleanliness.—The cleanliness incident to handling and using oil is too manifest to need argument. The coals obtainable on the Pacific Coast, at least, produce great quantities of dust, soot, and ashes. With any proper care in the handling of oil, all these disadvantages may be done away with, and the boiler-room kept as clean as a well-regulated engine-room. In many lines of business, this is a very important matter to the user of fuel, and where oil is in general use, as it is in San Francisco, the alteration in the appearance of the city, due to the removal of the smoke from coal fires, is very great.

Labor.—The labor of handling, and most of the labor of stoking, are done away with, though oil fires naturally require some attention. The greatest saving of labor, after that of firing, is in the cleaning of fires and flues. Oil fuel does away, of course, with clinkers, and therefore with the very trying labor of slicing and cleaning fires, while if properly regulated the boiler flues may be kept much cleaner. The latter not only reduces the labor of keeping the flues clean, but also considerably reduces the waste of fuel through imperfect transference of heat through the tubes to the boiler water. The removal of the necessity of constantly opening and shutting fire-doors reduces strains on both brickwork and boilers, prolonging the life of both, though this advantage may readily be lost by carelessness in handling an oil fire, due to the greater ease with which the latter may be forced.

Regulation.—The ease of regulation is a great factor in the economy realized in the use of oil fuel. The fire may be kept at a constant point for hours at a time, or may by the turn of a valve be made to respond to the most unusual demands for power. Where the call for steam is fluctuating, as on locomotives, where the demand for power may fall within a few seconds from the maximum capacity of the apparatus to absolute zero, this is of great importance. By the simplest contrivances and the most ordinary attention, the needle of the steam gauge on a heavy freight locomotive may be kept almost stationary, up hill and down, and through stops of any length. This ease of regulation is perhaps most appreciated where temperature is a factor, as in running an oil still or in heating metals. The temperature of an oil still may be regulated to a nicety and with the greatest ease, while every one called on to heat iron or steel will appreciate the ease with which the right temperature for forging or other operations is reached and maintained.

Capacity.—The increase in steaming capacity of boilers is considerable. There is some disagreement as to figures, but it would certainly be conservative to claim that, with a proper oil installation, a boiler may be made to deliver from 30% to 50% more steam than could possibly be gotten from it with coal, without the use of forced draft.[1]

But these points, while all important enough, are subordinate to the question of cost, in the mind of the average consumer. The great economy in the use of oil (at present prices) has been too thoroughly demonstrated to permit of any question, yet it may be permissible to point out briefly the reasons for and the extent of this economy.

Economy.—Theoretically, the saving realized from the use of liquid fuel depends on three factors: first, the less cost of the fuel per unit of heating value; second, the greater efficiency of the fuel, that is, the greater proportion of the ultimate heating value which may be actually developed around or under the object to be heated, or in other words, the possibility of more perfect combustion; third, the avoidance of loss of heat in various ways.

The first point is by far the most important, as it can be shown that, theoretical heating values being equal, oil costs only from one half to three fourths as much as coal. Let us take as an instance the case of a small consumer, who would pay about $6 per ton (2240 lbs.) for average coast coal, or 65 cents per barrel (in carloads, at present prices, Feb. 1904) for crude oil. Coal at $6 per ton costs 0.268 of a cent per pound. A barrel of 15° oil weighs 337 pounds, making the cost at 65 cents per barrel equal 0.193 of a cent per pound. Assuming the calorific value of 15° oil to be 18,360 B. T. U., and of average coast coal to be 12,600 B. T. U. (and the latter figure is more than fair to the coal), the cost of each fuel per 1000 B. T. U. would be:

$$\text{For the coal, } 0.268\text{c.} \times 1000 \div 12{,}600 = 0.0213 \text{ cent;}$$
$$\text{For the oil, } 0.193\text{c.} \times 1000 \div 18{,}360 = 0.0105 \text{ cent;}$$

i. e., the cost of the coal would be exactly twice that of the oil. But while the small consumer can buy oil almost as cheaply as the large consumer, this is not the case with coal, which can be contracted in quantities at lower figures. With coal at $5 per ton the cost of coal would be 1.66 times that of oil; with coal at $5.50 per ton, 1.83 times. These are theoretical heating values only, and in practice, owing to the greater percentage of efficiency of oil, the comparative cost of coal is somewhat greater.

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[1] See Tables 5 and 16; also compare capacity figures in Tables 20 and 21 with the capacity of the same boilers with coal.—Hutton, Steam Boiler Const., pp. 554-5.

It has been pretty well proven in practice that, under average conditions, four barrels of California oil would do the work of one ton of average coast coal. Four barrels of 15° oil would weigh 1348 pounds, and the heating value at 18,360 B. T. U. per pound would be 24,739,280 B. T. U. One ton (2240 lbs.) of coal, at 12,600 B. T. U. per pound, would have the heating value of 28,224,000 B. T. U. Oil with the heating value of 24,750,000 units will therefore do the work of coal with the heating value of 28,250,000 units, a difference of 3,500,000 units, or slightly over 12% of the heating value of the coal. For the explanation of this saving of heat, which of course means simply that a larger proportion of the available heat in the fuel is put to actual use, we must look to the second factor of economy.

The losses suffered in burning any kind of a fuel under a boiler arise in part in the escape of unburned fuel in its original form through the grate bars, in part in the escape of unburned combustible gases through the stack. In burning coal, particularly a coal which forms much ash or a heavy clinker, a portion of the fuel will always fall between the grate bars without being burned. Clinkers and cinders always contain more or less coal, and where the clinkers are very hard, considerable fuel may be sliced down in this way and removed unburned. Where coal is fine or dusty, a good deal will go through the bars with the ash. It has been found in some cases that ash from industrial establishments contained more than ten per cent of combustible matter, which, if the ash was ten per cent of the coal (a fair percentage on this coast) would equal one per cent of the coal. This is a small loss, certainly, but has its part in making up the total economy in burning liquid fuel. With oil this source of loss is entirely obviated. The only approach to such loss is where carbon forms on walls or bridges, from imperfect regulation of the burner. The most extreme case of such carbon formation which ever came under the writer's notice was where a cone-shaped lump weighing about 30 pounds was formed under a small boiler, during a two days' run, the amount of oil burned in this time being approximately 675 pounds. The loss here was almost four and one half per cent, as the carbon was removed for examination; in all ordinary cases such formations are stopped by proper regulation of the burner, and the deposit allowed to burn away slowly, without any loss whatever. It goes without saying that to allow unburned oil to accumulate in the ashpit, or to flow out on the boiler-room floor, as may occasionally be seen, is the grossest carelessness.

Combustion.—A much more important saving is realized through the perfect combustion of the gases in the firebox. It would be better to say may be realized, as this is a matter where the skill and attentiveness of the fireman, as well as the care taken in designing the firebox, are brought very much into evidence. There is hardly a doubt, however, that it is now possible to secure with oil a much more complete combustion than may be had with bituminous coal under any ordinary conditions, and that the skill on the part of the fireman which, applied to the burning of coal, would secure very mediocre results, will obtain very much better results in this respect when applied to the burning of oil.

It is a well-known fact that the flames from the fire beneath a boiler are immediately quenched on entering the mouths of the tubes, and that any gases not burned before reaching this point will not be burned at all, but will pass out of the flues into the stack, having parted with only a portion of their available heat. For this reason it is very evident that it is important to burn the gases as completely as possible immediately under the boiler. But at the same time it is necessary to limit the amount of air entering the firebox, for two reasons: that the air passing through the fire will go out of the stack at a much higher temperature than that at which it entered the firebox, thus carrying away part of the heat; and that an excess of air at any one point may cool the combustible gases below the point at which they will ignite, thus causing them to pass away unburned. To obtain perfect combustion with the minimum quantity of air, it is necessary to completely mix the air with the combustible gases. This may be done completely in burning gas proper (*e. g.*, coal gas), as may be seen in the small gas burners used by chemists and known as Bunsen burners, but in burning solid or liquid fuel it may be done only in part. It may easily be shown, however, that this mixture of the combustible gases with the necessary air may be obtained much more readily when burning oil than when burning bituminous coal, and that it is possible to keep the amount of air used in combustion much nearer to its proper point.

In burning bituminous coal on a grate, the coal is first distilled with the production of combustible gases, and these gases then burn. When fresh fuel is thrown on a fire, it is heated by the coal already burning, the heat causes it to distill, when it gives off inflammable vapors and gases, which burn in the fire space, causing flame. The coke left behind by this distillation is then further heated until it ignites, and gradually burns away, but without flame. As it burns it gradually shrinks in bulk, until nothing remains but a layer of ash, which continually works its way through the grate bars into the ash-pit. A coal fire, then, consists of four parts: a layer of ash on the grates; a layer of red-hot coke above the ash, burning, but without flame; a layer of fresh coal above the coke, not burning, but giving off combustible vapors and gases; and above all, the burning gases, or flame. With ordinary bituminous coal, about half the heat is generated by the burning gases, the other half by the burning coke, so that if any large part of the gases pass off unburned, the loss may be considerable.

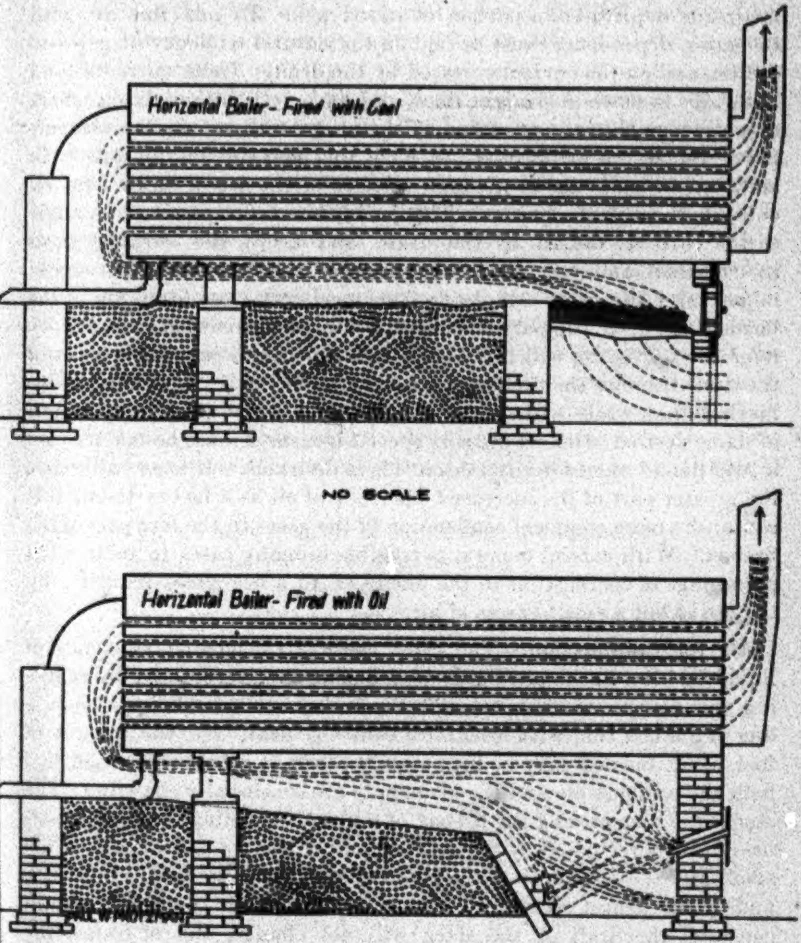
Horizontal Boiler - Fired with Coal
NO SCALE
Horizontal Boiler - Fired with Oil

FIG. 20. Showing Course of Draft, etc., Coal- and Oil-Burning Boilers.

As above said, to burn these gases they must be mixed with the right amount of air, as any portion of the gas not coming into contact with air before entering the flues will escape unburned. Now, in a coal fire, a large part of the air necessary for combustion must enter through the ashpit, and therefore pass up through the layer of ash and the burning coke, and the air which mixes with the combustible gases above is already deprived of a portion of its oxygen. To mix this air with the gases, dependence must be had on the natural tendency of gases to diffuse, and on the currents created by the draft. These currents tend naturally to move in straight lines, and have very little mixing effect, except where thrown out of line by the bridge wall or similar obstruction. But where oil is used, we have the powerful mixing effect, in addition, which is due to the high velocity of the jet of steam and oil entering through the burner. This jet is almost always set at an angle to the currents caused by the draft, and keeps the burning gases in continual and very strong agitation, so that they are thoroughly mixed, and the gases completely consumed very close to the tip of the burner. (These comparisons may be made somewhat clearer by reference to Fig. 20, which indicates in a general manner the course of the draft through the firebox of a horizontal boiler.) This effect is so marked that while with a coal fire it is easy to get almost any length of flame desired, with oil burners special measures must be taken to get a long flame, when for any reason this is desirable. It is probable that the greater part of the increased efficiency of oil as a fuel is due to this cause: the more complete combustion of the gases in the fore part of the firebox. With careful firing it is possible in many cases to reduce the percentage of combustible in the flue gases to a negligible quantity, by the use of but a small excess of air.

Air for Combustion.—The third cause of the greater efficiency of liquid fuel lies in the possibility of reducing the loss of heat, by reducing the amount of air taken into the firebox. That this is possible is due to the fact that with an oil fire both the draft and the amount of fuel being burned may be kept nearly constant, while with solid fuel both the combustible and the air supply are continually changing. The amount of air entering the firebox of a furnace burning coal under natural draft is regulated by the draft or pull of the hot gases rising in the stack, and the resistance to the entering air offered by the layer of fuel, and by the ashpit openings. So long as atmospheric conditions remain constant, the draft of the stack will not change, and of course the resistance of the ashpit openings will not vary except as intentionally changed by adjustment of the ash-doors. It follows, then, that if the resistance to draft of the bed of fuel should change, the other factors being constant, the amount of air entering the firebox would also change, and it will be seen that this change will always be in the wrong direction. The densest part of the fire, and therefore the part most tending to restrict the draft, is the layer of comparatively fresh fuel on top. As this layer is gradually distilled down to coke, after the addition of a fresh supply, it becomes more open, and therefore the quantity of air passing through it will increase. But on the other hand, it is at the time when fresh coal is being distilled down to coke, and therefore the greatest quantity of combustible gas is being given off, that the greatest quantity of air is needed to consume this gas completely. As the smallest quantity of air is passing through the fire at the time when the greatest quantity is needed, it is evident that the draft must be so regulated that the maximum quantity will be passing through at all times, and therefore when the bed of fuel is the most burned out, that is, just before refiring, a considerable excess of air will be passing through the firebox and carrying off heat with it to the stack. The extent of the loss from this cause may be greater or less according to circumstances. In very large fireboxes, where the bed of fuel is thick at all times, it may become very small, and where large quantities are required to maintain the fire, it is possible to add the fuel so gradually, especially if mechanical stoking appliances are used, as to keep the conditions in the firebox practically uniform. But where the fires are small, and particularly where they are thin, the losses from this source may become a serious percentage of the total value of the fuel.

To sum up, we have in favor of liquid fuel, the following points:

Ease of transportation and handling.
Reduction of storage bulk.
Increased cleanliness both inside and outside of boiler-room.
Reduced labor in firing.
Reduced cost per unit of heating value.
Increased percentage of efficiency.
Increased steaming capacity of generators.
Greater ease of regulation.

All these advantages taken together make up the well-known and (at present) very great economy in the use of fuel oil. What the saving will be in any particular case will depend on the relative importance of the various factors, and as these vary the saving will vary. So that, while we may say with perfect safety that in almost every case there will be considerable saving resulting from the use of oil fuel, it is very difficult to say just what the saving will be in any particular case, except by actual trial, followed by a very careful analysis of the results. But if we bring the matter down to a basis of comparative price

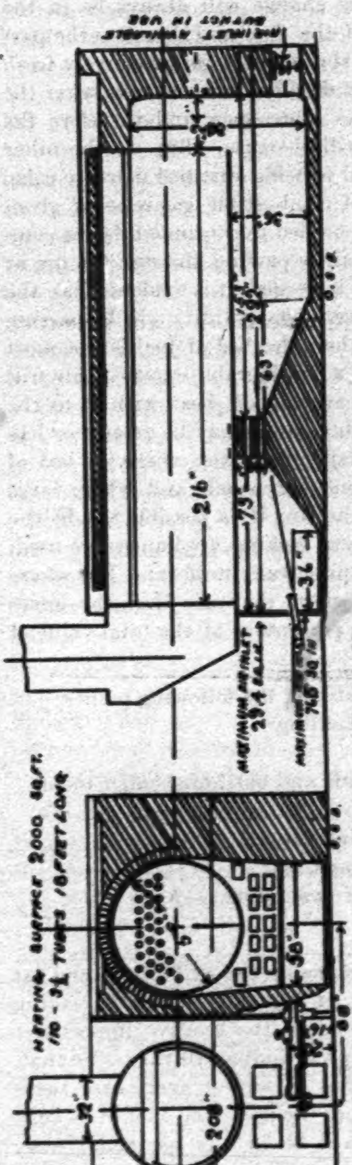
HEATING SURFACE 2000 SQ.FT.
110 - 3½ TUBES 16 FEET LONG
MAXIMUM AIR INLET 29.4 SQ.IN.
216"
36"
63"
79"
36"
511"
208"
32"
58"

Figure 20b

Stationary Boiler Settings - Santa Fe Shops - San Bernardino

and efficiency, neglecting such matters as labor and cleanliness (generally of minor importance), we may get at some fairly accurate comparisons.

Horizontal Boiler Trials.—The following table (No. 5) contains a record of tests made with horizontal tubular boilers, under different conditions. These columns are not strictly comparable, being made with two different sets of apparatus.

Column 1 gives results obtained by the Santa Fé Railroad Company, on a stationary boiler in the shop at San Bernardino, using 19.3° Fullerton crude.

Column 2, the same, but using 19.6° Fullerton oil.

Column 3, the same, using 12° Kern oil.

The boiler used in these three tests was the same, being a 60" x 18' horizontal tubular, with 1600 square feet heating surface. (See Fig. 20b.) These figures were obtained by Mr. O. S. Breese through the courtesy of the Mechanical Department, A. T. & S. F. R. R.

Column 4 gives figures obtained with a 72" x 18' horizontal tubular boiler with one hundred 2½" tubes, burning Beaumont crude oil.

Column 5 gives figures made with the same boiler, using "buckwheat" anthracite coal.

The figures in these columns (4 and 5) are from a series of tests made by Prof. J. E. Denton, in November, 1901. (See "The Engineer," February 15, 1902.)

TABLE 5.

	1.	2.	3.	4.	5.
Fuel used..*lbs.*	14,142	17,616	16,330	5,393	5,517
Calorific value........................*B. T. U.*	19,500	19,500	18,200	19,080	12,100
Theoretical evaporative power per pound of fuel, from and at 212° F.....................*lbs.*	20.20	20.20	18.85	19.74	12.53
Water evaporated from and at 212° F.......*lbs.*	188,042	248,472	219,156	83,542	49,309
Evaporation per pound of fuel as fired, gross..*lbs.*	13.29	14.10	13.18	15.49	8.94
Steam used in injecting..................*per cent*	....	....	....	4.8	....
Net available evaporation per pound of fuel..*lbs.*	....	....	....	14.75	8.94
Efficiency: percentage of theoretical heating value realized in actual evaporation...*per cent*	Gross. 65.8	Gross. 69.8	Gross. 69.9	Net. 74.7	Net. 71.3
Evaporation per hour per square foot of heating surface..................................*lbs.*	5.45	5.55	5.27	4.06	2.21

The tables below give the details of the tests summarized in columns 1, 2, and 3:

TABLE 6. DETAILS OF EVAPORATIVE TESTS BY SANTA FE RAILROAD.

Fullerton Oil. (See Column 1 in Table 5.)

DATE-1902.	Number of Test...	Duration of Test.		WATER.		OIL.		Water Evaporated per Pound of Oil.	Equivalent Evaporation from and at 212° F........	Average Boiler Pressure.........	Average Temperature of Water...	Average Temperature of Oil......	Gravity of Oil at 60° F...........
				Total.	Per Hour.	Total.	Per Hour.						
		hrs.	*min.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*deg. F.*	*deg. F.*	*deg. B.*
August 16..	1	5	35	40,431	7,240	3,515	630	11.50	13.60	88.5	72	94½	19.3
August 18..	2	4	0	29,751	7,438	2,690	673	11.06	13.06	89.1	73½	85	18.8
August 18..	3	4	30	34,045	7,566	3,016	670	11.29	13.36	91.0	72	92	19.0
August 19..	4	4	0	28,412	7,103	2,608	652	11.89	12.98	90.1	68½	82	*
August 19..	5	3	30	26,174	7,478	2,313	661	11.32	13.42	88.3	69	86	*
Average..	......	......	......	......	......	......	......	11.23	13.27	89.4	71	88.3	19.3

*Ordinary Olinda crude oil, which will average 19° Baume.

TABLE 7. DETAILS OF EVAPORATIVE TESTS BY SANTA FE RAILROAD.

Fullerton Oil. (See Column 2 in Table 5.)

DATE-1902.	Number of Test	Duration of Test.		WATER.		OIL.		Water Evaporated per Pound of Oil.	Equivalent Evaporation from and at 212° F.	Average Boiler Pressure	Average Temperature of Water	Average Temperature of Oil	Gravity of Oil at 60° F.
				Total.	Per Hour.	Total.	Per Hour.						
		hrs.	*min.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*deg. F.*	*deg. F.*	*deg. B.*
August 20	1	4	0	29,427	7,357	2,588	647	11.37	13.48	88.5	69	80½	19.55
August 20	2	4	30	26,981	5,996	2,364	525	11.41	13.52	89.3	70½	85½	19.55
August 21	3	4	0	26,370	6,593	2,190	548	12.04	14.28	89.0	68½	85½	19.65
August 21	4	4	32	32,011	7,066	2,629	580	12.13	14.37	88.6	70	91½	19.45
August 22	5	4	0	29,721	7,430	2,577	644	11.53	13.69	89.8	68½	84½	19.80
August 22	6	4	33	31,369	6,894	2,619	582	11.84	14.03	89.0	70	93	19.20
August 23	7	4	0	30,925	7,731	2,649	662	11.67	13.85	89.1	68½	84½	19.75
Average								11.72	13.89	89.0	69.3	86.4	19.56

Special Olinda oil from Santa Fe Well No. 26.

TABLE 8. DETAILS OF EVAPORATIVE TESTS BY SANTA FE RAILROAD.

Kern Oil. (See Column 3 in Table 5.)

DATE-1902.	Number of Test	Duration of Test.		WATER.		OIL.		Water Evaporated per Pound of Oil.	Equivalent Evaporation from and at 212° F.	Average Boiler Pressure	Average Temperature of Water	Average Temperature of Oil	Gravity of Oil at 60° F.
				Total.	Per Hour.	Total.	Per Hour.						
		hrs.	*min.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*lbs.*	*deg. F.*	*deg. F.*	*deg. B.*
October 23	1	3	28	26,136	7,540	2,404	693	10.90	12.95	93.1	68	110	------
October 23	2	4	0	28,058	7,015	2,506	627	11.19	13.27	86.4	67½	124	13.8
October 24	3	4	1	28,506	7,091	2,567	639	11.10	13.21	90.0	65	117	13.4
October 24	4	3	50	24,110	6,295	2,170	567	11.11	13.21	87.8	66	144	11.7
October 25	5	4	0	21,900	5,475	1,936	484	11.31	13.48	93.6	64½	140	11.2
October 28	6	4	0	26,019	6,505	2,302	576	11.30	13.45	89.7	65½	147	11.4
October 28	7	4	0	26,687	6,672	2,445	611	10.92	12.90	91.0	72	160	10.9
Average								11.12	13.21	90.2	67	135	12.1

Evaporation per Pound.—These tests, of which a large number might be quoted, would seem to justify the statement that, under ordinary conditions, oil burned under horizontal tubular boilers should give an evaporation of from 13½ to 15 pounds of water per pound of oil. To compare this with the performance of coal is a very difficult matter, as while almost all kinds of (clean) oil give about the same results under identical conditions, it is well known that the evaporative power of different coals varies enormously. There is considerable coal sold on the Pacific Coast which will not evaporate more than 5 pounds of water per pound of coal as fired, while others can be made to evaporate as high as 11 pounds. But it is probably fair (to the coal, at least) to say that run-of-mine steam coal, as shipped into San Francisco, will average not far from 8 pounds actual evaporation from and at 212° F. at an efficiency of 70%, equal to a theoretical evaporative power of 11.4 pounds, or a calorific value of 11,340 B. T. U.

At an average evaporation of 8 pounds for coal and 14 pounds for oil, 1 pound of oil would be directly equal to 1¾ pounds of coal, or one ton (2240 lbs.) of coal to 1280 pounds or 3.8 barrels of oil. So when we say that four barrels of oil are equal to a ton of coal for steam making, the expression, while entirely true and conservative as applied to average fuels and local conditions, may not hold good in every case.

Comparison of Costs.—With oil at 65 cents per barrel, coal which will evaporate 5 pounds of water per pound is worth, in comparison, $1.56 per long ton. Average coast coal, good for an evaporation of 8 pounds of water, is worth $2.48, while very high-grade coals, capable of evaporating 11 pounds of water per pound, are worth $3.40 per ton for steam generation in competition with oil.

The table following shows the relative actual cost of coal and oil at various prices for each. This table is based on a relative value of four barrels of oil to the (long) ton of coal, and the figures given show the *cost*, at various rates per ton, *of the amount of coal required to do the work of an amount of oil costing $1*, at the different prices named for oil.

TABLE 9. COMPARATIVE COST OF COAL AND OIL.

COAL—per Ton.	OIL—per Barrel.										
	$1 00	$0 95	$0 90	$0 85	$0 80	$0 75	$0 70	$0 65	$0 60	$0 55	$0 50
$4 00	$1 00	$1 05	$1 11	$1 18	$1 25	$1 33	$1 43	$1 54	$1 66	$1 82	$2 00
4 50	1 12	1 18	1 25	1 32	1 41	1 50	1 61	1 73	1 87	2 04	2 25
5 00	1 25	1 32	1 39	1 47	1 57	1 66	1 79	1 92	2 08	2 27	2 50
5 50	1 37	1 45	1 53	1 62	1 72	1 83	1 96	2 11	2 29	2 50	2 75
6 00	1 50	1 58	1 67	1 77	1 88	2 00	2 14	2 31	2 50	2 73	3 00
6 50	1 67	1 71	1 81	1 91	2 03	2 17	2 32	2 50	2 71	2 95	3 25
7 00	1 75	1 84	1 94	2 06	2 19	2 33	2 50	2 69	2 92	3 18	3 50
7 50	1 87	1 97	2 08	2 21	2 34	2 50	2 68	2 88	3 13	3 41	3 75
8 00	2 00	2 11	2 22	2 35	2 50	2 67	2 86	3 08	3 33	3 64	4 00

It should always be borne in mind, in making comparisons of this sort, that no general rule can give other than average results. In some cases the coal would make a better showing than the above, in others worse, depending on the quality of the coal, the quality of the oil, and the nature of the work to be done. The above figures purport only to compare the ordinary British Columbia coal of fair quality, with an average grade of Kern River or similar oil, for use in steam generation under normal conditions.

As an illustration: In Sacramento, average steam coal is quoted at $7.50, carloads,[1] while fuel oil sells at 65 cents. At these rates the steam user receiving an ordinary grade of coal pays at least two and nine-tenths times as much for his fuel as his competitor using oil, or in other words, his ton of coal could be replaced by oil costing $2.60.

At Salinas, coal is quoted at $7.00, oil at 80 cents,[2] making coal cost some two and two-tenths times as much as oil, or $3.20 for oil to replace a ton of coal.

At Los Angeles, fuel oil is sold at 75 cents, coal at $8 up.[3] A ton of $8 coal at Los Angeles costs about two and six-tenths times the price of an equivalent amount of oil, the latter being $3 or less per ton equivalent.

At Santa Barbara, steam coal is quoted at $9.50 per ton, Summerland oil at 80 cents per barrel.[4] This makes the cost of coal about three times that of oil, the cost of the oil to replace a ton of coal being not far from $3.20.

At Redding, pine wood is quoted at $3.50 per cord.[5] A cord of pine wood equals, roughly speaking, two and one-half barrels of fuel oil. The latter can be laid down at Redding, carloads, for $1.06 per barrel, or $2.65 for the equivalent of a cord of wood.

At San Luis Obispo, oil is quoted at 75 cents, wood at $4.50 per cord.[6] At this rate, a cord of wood costs some two and four-tenths times as much as an equivalent quantity of oil, the cost of the latter being $1.88 for the equivalent of a cord of wood.

At Auburn, pine wood is quoted at $4 per cord; fuel oil can be had at 97½ cents per barrel.[7] This makes wood cost at least twenty-three per cent more than oil, although Auburn is situated very close to a timbered country, and far from oil supply.

It would seem that oil can compete with solid fuel at all parts of the State, except perhaps in upper Mendocino and in Humboldt County.

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[1] Communication from Sacramento Chamber of Commerce.

[2] Communication from Chamber of Commerce, Salinas, February 13, 1904.

[3] Communication from Los Angeles Chamber of Commerce, January 15, 1904.

[4] Communication from A. W. Grant, Summerland.

[5] Communication from Board of Trade, Redding.

[6] Communication from Board of Trade, San Luis Obispo, January 20, 1904.

[7] Communication from Placer County Improvement and Development Association.

CHAPTER 6.

INJECTION AND BURNERS.

The first necessity in burning fuel oil economically is to atomize the oil finely into the firebox. Whether steam or air be used as the injecting agent, the oil must be broken by it into the finest possible spray, while at the same time the steam or air used must be reduced to the smallest possible quantity, both on account of the cost of steam or of compressed air, and on account of the waste of heat due to use of an excess of either. The necessity of atomizing the oil completely is probably apparent enough, yet a short explanation may make it clearer to some who have not thought out the process by which oil is consumed in the firebox.

It is well known that before liquid fuel can be consumed by the air passing through the firebox, it must be converted to a state of vapor by the radiant heat of the firebox walls. When oils are vaporized, or more simply, boiled, they leave behind a residue of coke. So when a particle of oil leaves the nose of the burner, it immediately commences to evaporate in the high heat of the furnace, at the same time traveling across the furnace with the velocity imparted to it by the steam jet, until the liquid portion is completely changed to gas, when the residue, a tiny speck of coke, will also burn. But if the drop leaving the nose of the burner is too large to evaporate completely in the time it takes to travel across the furnace, the residue will not be burned, but will be projected against the target, side wall, or bridge, whatever solid body happens to be in its way, and will stick there. If the particles striking the target or other obstruction are dry carbon, the deposit of carbon formed on the target will not be very hard, and will burn off in the course of time, if the accumulation stops for any cause; but if the particles are of the consistency of asphalt, as is more likely to be the case, they will form a carbon deposit of great hardness. This carbon deposit is necessarily formed in the axis of the jet cast by the burner, that is, in the line where the jet of flame impinging on the wall is turned out and back by the resistance, and being thus in the center of the flame is practically protected from the air currents of the firebox. Thus protected, it of course can not burn off, and will accumulate just so long as the supply of unburned oil continues.

This deposit of carbon causes a number of undesirable results. In the first place, it wastes an appreciable portion of the fuel. Then again, oil thus thrown against furnace walls or targets vaporizes slowly and imperfectly, and the vapor, being drawn along the fire-floor, does not mix readily with the air supply, but is likely to be drawn out partly unburned, causing waste and smoke. And finally, if a boiler furnace particularly is being forced to its utmost capacity, a deposit of carbon is likely to seriously disturb the draft conditions of the furnace, causing great waste and a loss of steaming capacity. This is particularly objectionable in the small fireboxes of locomotives, where the carbon from an imperfectly adjusted burner may have to be broken down at frequent intervals to enable the engine to hold its steam.

In internally fired boilers the necessity of complete atomization is still more strongly felt. It is apparent that the smaller the particles of oil leaving the burner, the finer will be the carbon dust left by the evaporation of these particles. As carbon burns slowly compared with gas, the portion of the flame farthest from the burner will be due in large part to solid carbon, and the larger and slower burning these particles of carbon, the longer will be the flame. If the flame be too long, in such a boiler as this, it will reach the back connection sheet, causing injury to it and to the staybolt heads, while to protect these parts with firebrick materially reduces the heating surface of the boiler.

Types of Burners.—To meet the necessity for perfect atomization, and to minimize the quantity of steam or air required to do the work in the best manner, a great variety of burners, simple and complicated, has been invented. Many of these contrivances show great ingenuity, and bear very little resemblance, in appearance, to the original, yet in principle there has been no departure from the method devised some fifty years ago, the only burners embodying a new principle (the retorting or gasifying burners) having fallen into practical disuse some time since.

Essentially, the oil burner is simply a spray, resembling very closely the ordinary steam jet ejector, a stream of steam or air (any other gas would do as well) being depended on to break a smaller stream of oil into minute drops, and to throw these with some force from the nozzle of the burner. The first and most important point in the proper working of a burner is, as has already been noted, to break the oil into the finest possible drops, and this with the least possible consumption of the atomizing agent, whether steam or air. Other points of more or less importance are: that the burner should throw a flame of length and size proportioned to the size of the firebox, that the oil should be completely consumed without the formation of smoke or of carbon deposits, that the flame should be steady and not too noisy, that the burner should be readily regulated without tedious adjustment and readjustment of steam to oil, that the burner should be capable of carrying a small flame without breaking, and of throwing a clear flame into a cold firebox, and finally that the burner proper should be durable, not readily burned if left to stand unused in place in a hot furnace, and that it should not be likely to become choked, either in use, from dirt in the oil, or when turned off, from carbonization of oil remaining in the burner.

Even were it possible, from the point of view of space, to point out the relative merits of all the burners on the market, this would hardly be the place to do so. But it may be pertinent to describe briefly the most important *types* of injectors, showing the efforts which have been made to overcome particular defects or to secure particular advantages, and leaving it to individual judgment to select the type most suitable to the work in hand.

It should be noted that the particular makes of burners here illustrated were not selected on their merits, but such were taken as showed the typical principle in the most comprehensible manner. As practically all burners are patented contrivances, it was necessary to give the names of the burners illustrated, but no recommendation or discrimination is intended, the remarks applying to the general type only.

The original and simplest form is the **pipe burner**, as shown at "A" in Fig. 21. This probably needs no explanation; the sizes of the tubes, which are ordinary black pipe, are governed by the amount of oil to be burned, and by other conditions, but in general a burner made up from 1" outside and ¼" inside will meet the usual requirements. The length is varied with the thickness of furnace front through which the burner is to extend, and need not be greater than enough to allow for 4" or 5" projection inside, there being little if any advantage in longer tubes. The steam opening may with advantage be bushed to ¾", and should have a globe valve of the best quality, the packing on the valve stem being jammed up enough to make the valve work rather stiff. The oil end should have a brass needle valve, preferably one with a long steel needle, which is considerably more sensitive than the ordinary short needle. The opening in these small valves may have to be drilled out to nearly the size of the body of needle, if either oil or work to be done is very heavy. The discharge ends of both oil and steam pipes should be drawn down to a round, true hole of the proper size; the size of the oil opening is not of much importance, except that it should be large enough to carry the full opening of the oil valve. The size of the nozzle on outer pipe is a very particular matter, and requires some care, yet no general rule can be laid down, as the proper size will vary with a number of conditions. It is well to make it small in the first place, from $\frac{3}{16}$" to ¼", and ream out from time to time, after trial, until the best results are had.

Where a flat flame is desired (the round nozzle naturally throws a round or cone-shaped flame) the arrangement shown in "B" may be used. This is simply a collar on the end of outer tube, holding a hollow plug which has been slotted through with a hack saw. The contrivance is rough, but can be made in a few minutes, is easy to replace at any time, and if dressed out with a fine warding or knife-edge file to the proper width of opening, can be made to give excellent results.

Where it is necessary to carry a very small flame, the burner shown at "C" may be used with good results. The construction is similar to that of the pipe burner, except that within the outer tube are slipped blank nipples of the next size smaller pipe (*e. g.*, ¾" in a 1" outer tube), alternating with discs of thin iron or brass, these discs with punched holes arranged in a circle, or better, with drilled holes placed at an angle with the axis of the burner. This burner, when properly adjusted (which requires care), atomizes quite finely, and may be made to carry a small flame without breaking. When the flame is to be very small, however, particularly if the temperature of the firebox is low, the

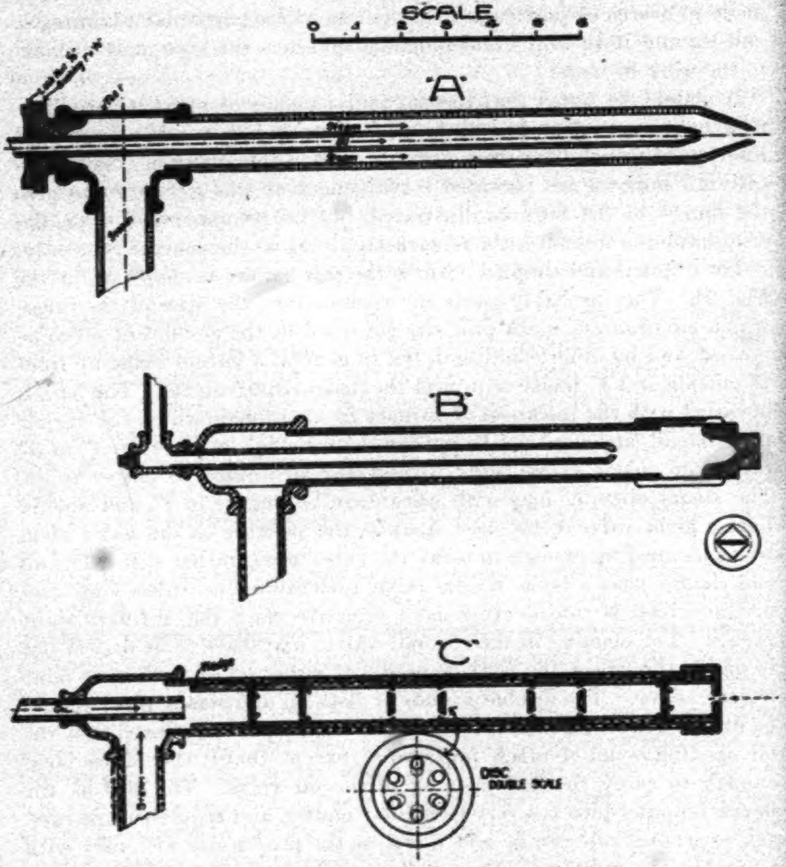


Fig. 21. Forms of "Pipe Burners."

steam used should be superheated, and if possible a combustion chamber should be arranged in front of the burner, in order to have a radiating surface close to the flame. In extreme cases it may be impossible, by any arrangement, to carry a small flame and a low heat with heavy crude, and in this case a light crude or a distillate must be used.

The pipe burner is an "inside mixing" burner; that is, steam and oil are brought into contact inside the outer shell, and therefore back of the jet. A modification of this form is found in the **block type** (Fig. 22), in which mixture is effected inside a heavy metallic block. This type of burner, of which there are a number of varieties, has the advantage of simplicity, may be readily cleaned, and occupies little space. It makes little or no attempt to heat the oil before ejecting, and if heavy oil is used, the latter must be heated. The burner illustrated throws a flat, fan-shaped flame, but others of this form are arranged to throw a round flame, the difference being purely in the shape of the nozzle. Burners of this class should be designed for the particular work to be done, as they do not work very well if conditions of steam and oil pressure are much varied; they also have a strong tendency to

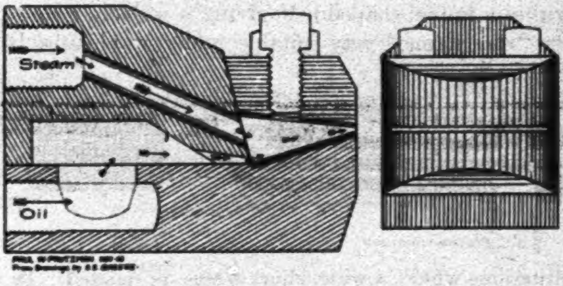
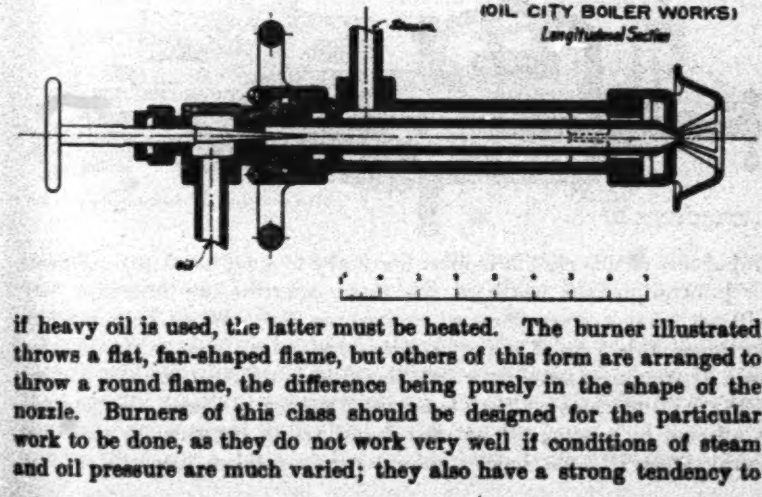


Figure 22
"INSIDE MIXING" BURNER
BLOCK TYPE
(HAMMEL BURNER)
Longitudinal Section and Side Elevation



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Bureau of Steam Engineering, U.S. Navy, 1902

Figure 23
"OUTSIDE MIXING" BURNER
TUBULAR TYPE
ROUND FLAME
(OIL CITY BOILER WORKS)
Longitudinal Section

clog in the slit, by the formation of hard carbon, and are not readily cleared while in place.

In "outside mixing" burners, oil and steam are brought in contact outside of the outer shell; that is, instead of ejecting a mixture of steam and of oil globules from the nose of the burner, the steam and oil are thrown out from separate jets, the oil stream being then caught up and sprayed by the velocity of the steam jet. In the **tubular type** shown in Fig. 23, a hollow jet of steam converges on a stream of oil within a funnel-shaped bell, giving a wide and short flame, known as the "rose flame," very suitable under water-tube boilers, or in other situations where a wide, short flame is desired. In other burners of this general type, the shape of the tip is such as to throw a longer and more solid flame. Many burners of this type are provided with an arrangement by which the width of the steam orifice may be varied, a very desirable feature, as it enables the burner to work well over a much wider range of conditions than is possible with a burner with apertures of fixed size.

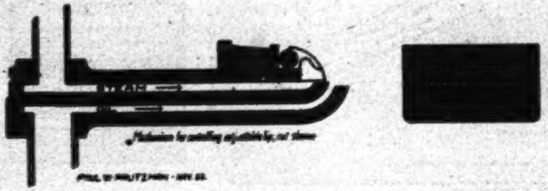


Figure 24
"OUTSIDE MIXING" BURNER
STUB TYPE
FLAT FLAME
(W-N-BEST BURNER)
Longitudinal Section & Face Elevation

In the **stub type** of "outside mixing" burners (Fig. 24) a jet of steam blows the oil from a shelf or pan below, or in other types the oil falls from above into the jet of steam, each method having some advantages.

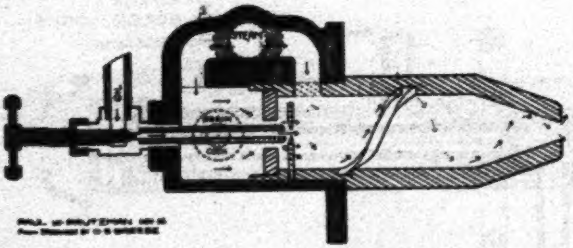
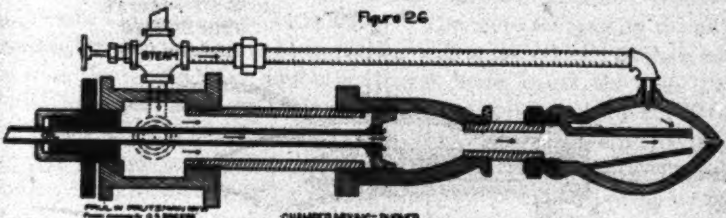


Figure 25
"INSIDE MIXING" BURNER
STUB TYPE
ROTARY FLAME
(UNION DRIP FORGE BURNER)
Longitudinal Section

In burners of this class it is most necessary to have some arrangement for controlling the width of the steam aperture, as otherwise they will not carry a clear flame when burning low. When properly proportioned, this form of burner has the same advantages as the tubular form, but requires some little skill in adjustment to get the best results.

Fig. 25 illustrates an "inside mixing" burner in which the mixture is effected by **rotating** the steam column within the tube by means of spiral ridges. In the burner shown, steam is taken into the tube at two points, in others of this form at one only; the difference is not very apparent. These burners throw a cone-shaped flame, rather shorter than that thrown by the simple tubular burner; the greater the degree of rotation attained, the shorter will be the flame. Like all "inside mixing" burners these have the disadvantage that there is no regulation of the steam orifice, and therefore the velocity of the jet, and with it the efficiency, falls when turned low.

Figure 26



"CHAMBER MIXING" BURNER
FLAT FLAME
(AMERICAN CRUDE BURNER)
Longitudinal Section

In burners of the "**chamber mixing**" type (Fig. 26) the oil is atomized by the first jet, and the mixture of steam and oil globules passes through one or more chambers, often being finally ejected by a second steam supply. The burner illustrated throws a flat flame through a slit, while a round nozzle would throw a cone-shaped flame. The complication of parts in burners of this class, of which there are several types, is a disadvantage, but there is no doubt that the passing of the mixture through and around ridges, corrugations, coiled wires, etc., assists in reducing the size of the oil particles finally ejected, and secures better atomization.

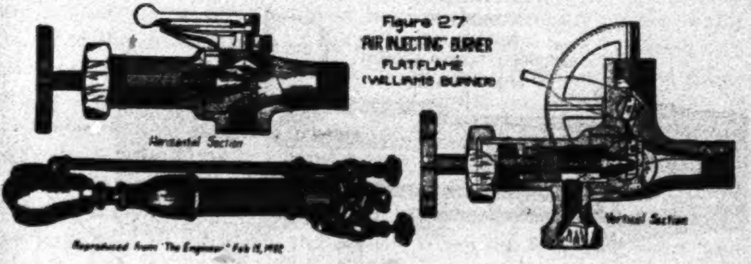


Figure 27
"AIR INJECTING" BURNER
FLAT FLAME
(WILLIAMS BURNER)

Reproduced from "The Engineer" Feb 15, 1912

In Fig. 27 is shown a burner of the same general class, the difference being that here the jet of steam is used also as an aspirator, to draw through the burner a **stream of air**, previously heated by passage through flues exposed to the heat of the furnace.

Fig. 28 shows a form of burner in which both **steam and air** are used, the steam jet atomizing the oil through the inner bell, while a stream of air passes out with the mixture through the outer bell. The object of the secondary air supply, whether aspirated by the burner or forced in by a blower, is to shorten the flame and add to its intensity, and where large amounts of oil have to be burned in small fireboxes, as in marine or locomotive work, the theory at least is good. The complication of such arrangements is troublesome, and where air is taken in through the burner, the flame is likely to be extremely noisy.

Reproduced from "Report of the Liquid Fuel Board" Bureau of Steam Engineering, U.S. Navy, 1902

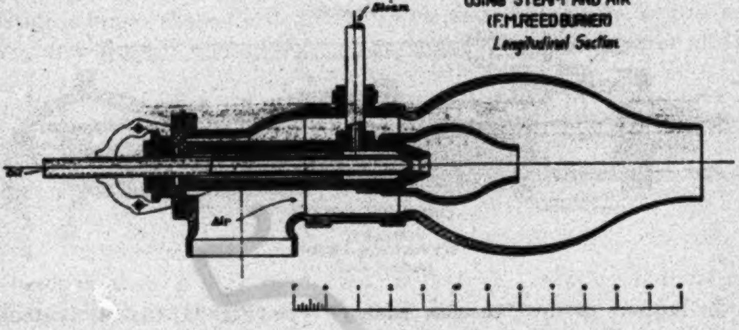


Figure 28
COMBINATION BURNER
USING STEAM AND AIR
(F.M.REED BURNER)
Longitudinal Section

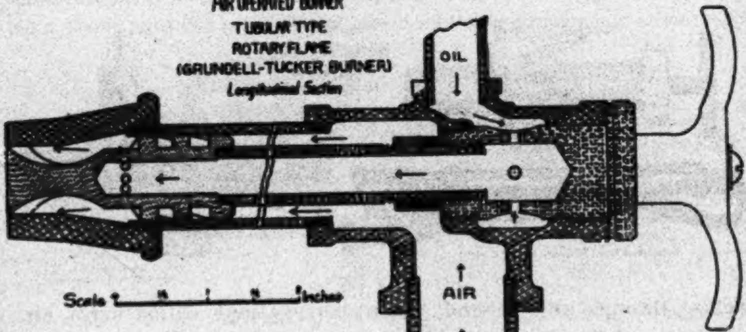


Figure 29
AIR OPERATED BURNER
TUBULAR TYPE
ROTARY FLAME
(GRUNDELL-TUCKER BURNER)
Longitudinal Section

An air-operated burner of the tubular type is shown in Fig. 29, the oil passing out of the inner tube through small holes at right angles to the stream of air, which latter has been set rotating by the spiral slots shown, and the mixture ejected in a hollow cone from the adjustable ring nose. This burner does not differ in any essential principle from some steam burners, though the adjustment for air is somewhat different from that required for steam.

Selection of Burner.—In the selection of an oil burner, the first consideration is its adaptability to the work to be done, as no one burner will answer for all situations if the greatest economy and best results are required. If a small, steady fire is to be kept up, and particularly if noise is objectionable, a burner of the "chamber mixing" type will usually be found the most satisfactory. The more thoroughly the oil is atomized within the burner body, the less will be the velocity of the steam jet from the burner nose; and other things being equal, the noise produced by a burner is proportional to the velocity of the jet. If the work to be done is heavy, without great fluctuations, a simpler type of tubular burner will give as good results, with less liability to breakdowns; in hard, steady firing a very important point is that the burner should be readily kept clean, both at the nose and within the tubes, and that it should be easy to replace without loss of time. Where the demands for steam are variable, an "outside mixing" burner with adjustable steam orifice will respond to regulation more readily than other types. To secure intense local heat, an air-injecting burner may be used, though the same results may often be obtained by manipulation of the draft.

Adjustment.—Whatever type of burner is used, it must be adjusted to the particular conditions to be met. The size of the flame must be adjusted to the dimensions of the firebox, by varying the relative sizes of the openings. It is evident that the flame proper should never reach any metallic parts, nor should it impinge too strongly on the walls. Owing to the intense heat of an oil fire, even the best fire-brick will soon crumble or melt if set too far up in the flame; and if the flame strikes the wall at short range, carbon deposits are hard to avoid. If the firebox is wide and flat, a slotted nozzle burner of some kind should be used, and the flame be spread evenly over the whole surface without directly playing on the side walls or the shell; while in a long, narrow firebox a round nozzle is better, that the nearest and hottest part of the flame may be kept from the walls. When the firebox is short and deep, as with a water-tube or an internally-fired boiler, a rose-flame burner may be so set as to carry the fire very close to the burner, and reduce danger of burning lower tubes or back connections. Where water-tube boilers are forced hard, this is often a very difficult matter, requiring much skill and ingenuity on the part of the engineer. Some contrivances for this purpose are shown in a later paragraph.

Installation.—Where any considerable amount of fuel is to be used, it is economy to put the installation of the burners in the hands of a person or firm skilled in the work. The adjustment of an oil burner to give the best results is a very delicate matter, requiring special knowledge on the part of engineer or mechanic, and the increased cost of installation by an expert will soon be returned in added economy, and reduced wear and tear on boilers and settings. A good burner, carefully adjusted, under a water-tube boiler, should consume approximately 4% of the steam generated by the boiler when running at or near rated capacity. As the steam used by the burner must be heated in the firebox to at least stack temperature before being discharged from the flues, every per cent of steam used by the burner reduces the available energy of the fuel by from 1¼% to 1½%. A burner consuming 6% of the steam generated by the boiler, not an uncommon occurrence, is eating up not less than 7% of the fuel, perhaps even 10%, while from 3% to 5% of this loss is absolute waste.

Economy in steam consumption seems, from the results of a number of competitive tests, to depend much less on the form of the burner than on the adaptability of that form to the special use, and on the skill exercised in the adjustment of the mechanism. The question is often debated as to the relative merits of the various patented burners, and their superiority to the simpler and unpatented forms. There can be no question that the patented burners, when installed by their inventors (naturally, men skilled in their adjustment), give better results than are ordinarily had with home-made burners installed by mechanics of no special skill in the matter. On the other hand, there is little doubt that an expert can, with the simplest form of pipe burner, nearly if not quite equal the best performance of the more expensive types. So while it is undoubtedly good policy to entrust the installation of a large fuel-oil plant to an oil-burner man, yet no prospective small consumer should be deterred from the use of oil by the cost of burners, as with care and the special skill which comes with practice the best results may be obtained, and even with the crudest contrivances the cost of liquid fuel may be made much less than that of either coal or wood.

Compressed Air.—The idea of using compressed air in place of steam as an injecting agent in oil burners early suggested itself, as it can readily be shown that the steam required to compress the air for a burner is but a small fraction of the amount required for the burner itself. There was thought to be the further advantage that the air would be supplied at the point most needed, at the center of the flame, and thus assist combustion. It seems now to be the general opinion that burners worked with air *at high pressure* throw too fierce and concentrated a flame, difficult to handle, and likely to burn out walls and boilers unless carefully controlled. There is the further drawback that the necessary apparatus and first cost are greatly increased, and that breakdowns are much more likely, nevertheless where water is expensive, as on shipboard, the system is very generally used. Some very satisfactory installations use air at low pressure (two to ten ounces). The results seem to be better as regards both economy and control of fire. The burners used with both systems are practically identical with those used with steam.

CHAPTER 7.

THE FIREBOX.

The proper construction of the firebox intended to burn oil is probably the most important matter connected with the installation of liquid fuel, while at the same time it is that part of the construction which has received least attention from engineers. The reason is easy to find: that the original installations of fuel-oil apparatus were in furnaces previously burning coal, that the least possible alteration was desired, on account of the cost of changes, and that the degree of economy realized in this crude manner was so great that incentive for improvement was lacking. Still it can not be doubted that the coal-burning furnace is particularly ill adapted for use with oil, and that a radical change in boiler-setting methods is desirable.

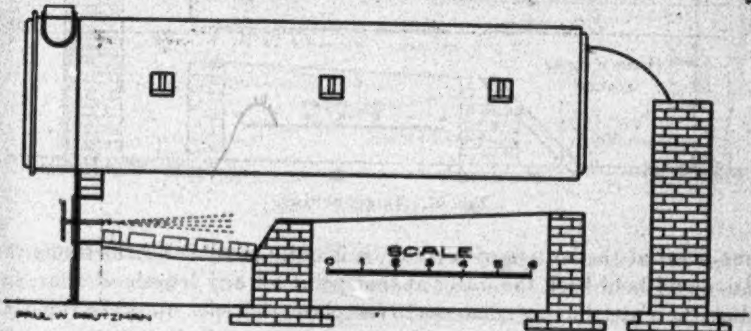


Fig. 56. Grate Bar Setting.

The common way of adapting the firebox of a horizontal boiler to use with oil (water-tube boilers are mentioned in Chapter 11) is to cover the grate bars with loose fire-brick, in a checker, leaving an opening under the nose of the burner, and to insert the burner through a hole in the boiler front, between the doors. (See Fig. 56.) The ash-pit openings are sometimes closed with brick, sometimes left open, and the bridge wall is leveled with the grates. The faults of this system are apparent enough: The burner points directly toward the back plate, and the velocity of the burner jet is usually such that combustion hardly commences further forward than three or four feet from the front. Under a small boiler, the hottest part of the fire is near the rear end, and if the fire is forced the back plate will often be raised to a red heat, with ruinous effect on rear tube sheet and tube ends, besides forcing considerable amounts of combustible gas into the stack unburned. If it is attempted to break the course of the flame by leaving the bridge wall in place, the flame will be forced directly against the fire sheet, causing blistering and sagging, even with good boiler circulation. Where a strong, steady flame is directed against one point at the bottom of a boiler, it is quite possible for the steam to drive and hold back the water at that point for any length of time, so that, the water having no access to the plate, this spot would be rapidly burnt out.

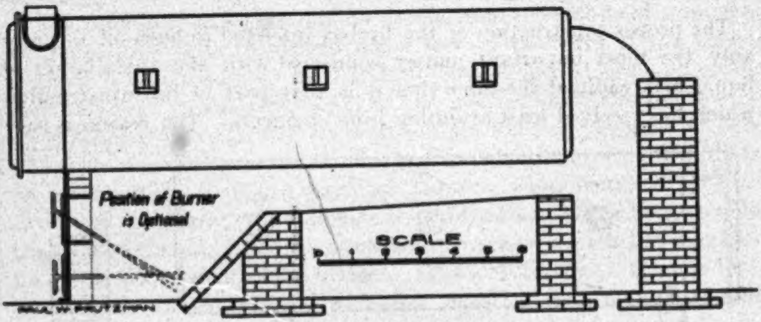


Fig. 57. Target Setting.

This method of firing oil is wasteful in the extreme, as well as very destructive, where the boiler is forced, though for very light work it will answer well enough. A burner for this setting should be of the flat-flame variety, and should spread the flame well up to the side walls. Some prefer to set the burner level, others to tip it slightly toward the brick covering the grates.

The setting generally used with oil stills is sometimes applied to boilers. (See Fig. 57.) The grates are removed, the bridge wall cut down to the height of the rear bearing bar, the back filling dressed off to an even slope, and a fire-brick target run from ground to top of bridge wall, inclined from 30° to 45° to the vertical. The burner is inserted through the front, and set so that the flame will strike in a pile of broken fire-brick near the bottom of target. The ashpit openings are closed with brick, only a small draft opening being left in each, and the firebox is lined with one or two courses of fire-brick to the bottom, as the heat is highest at that point. This setting gives excellent results, particularly with hard firing, gives the use of the entire lower surface of the boiler, and considerably reduces the amount of air required for combustion, as the burner jet is practically at right angles to the line of draft, and the flame rolls over in the fore part of the furnace before going over the bridge wall. With this setting it is necessary to regulate the draft very carefully, as an excess interferes with the proper working of fire.

A rather similar method (see Fig. 58) is to practically remove the bridge wall, and to bring the back filling to a nearly even slant from front to a rear bridge wall, leaving a circulating chamber at rear end.

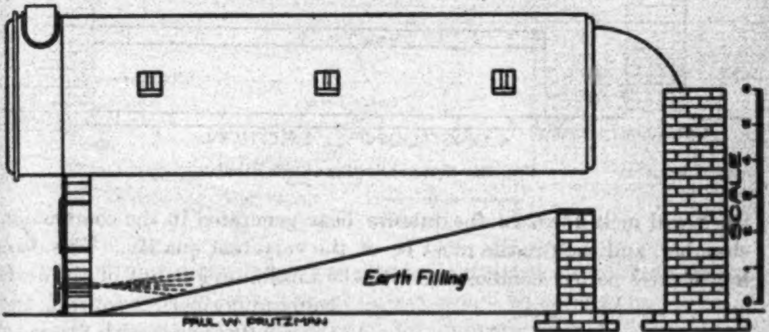


FIG. 58. Half Target Setting.

The burner is set low, and the flame strikes a pile of broken fire-brick placed about where the foot of bridge wall would be. This arrangement is less severe on the front fire sheet than the target setting above, but is rather less efficient as regards combustion. With either of these settings any form of burner may be used, either round or flat nozzle, though a round nozzle is probably better. If a round-nose burner is used, and the flame strikes the target squarely, carbon deposits are likely to form while the firebox is cool, but these will burn off as the heat rises.

With any form of target setting the cast boiler front is entirely unnecessary, a wall of red brick with fire-brick lining being as good or better. In any setting without grate bars it is obviously impossible to fire up with coal; wood may be used, or if oil can be gotten through the burner in any way, the boiler may be fired up with cold oil by flowing a small stream onto a pile of waste, burlap, or broken brick, in the center of the firebox. This method, which of course causes some smoke, is largely practiced in the oil fields.

To secure perfect combustion, and to obtain the full heating value of the fire gases without danger of burning tubes or back tube sheet, the setting shown in Figs. 59 and 60 was devised and used by Mr. Frank Fether, superintendent of the Monte Cristo Oil Company of Kern River. The tunnel is built of the best fire-brick, and covered in with fire-tile, of the dimensions shown, which are made to order. An arch made of fire-brick will melt down in the intense heat generated in the combustion chamber, and the fire-tile must be of the very best quality. This system secures perfect combustion with the minimum amount of air, draft being under perfect control, and the mixture of air with fire gases very thorough, and where a boiler is run twenty-four hours per day, is very economical. If a boiler is to be run day shift only, the setting is not very suitable, as the great mass of fire-brick in the combustion tunnel stores up a large quantity of heat, which is given off and practically lost during the night. The heat maintained while running is very even, but on account of the heat-storage capacity of the brickwork, does not respond very readily to varying demands for steam.

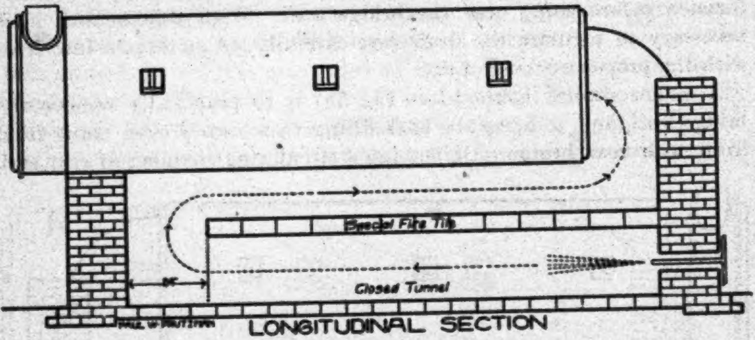


FIG. 59. Tunnel Setting, Back Fired.

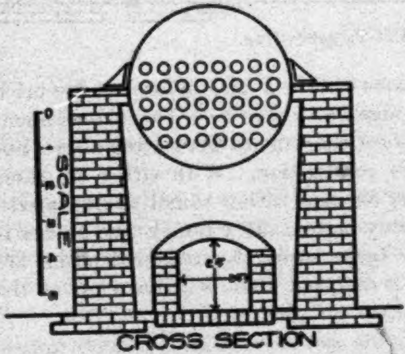


FIG. 60. Tunnel Setting, Back Fired.

To obtain the same results, *i. e.*, perfect combustion at the front end and close regulation of draft, the setting shown in Fig. 61 has been devised by Mr. E. N. Moor, superintendent of the Capitol refinery. The iron front is discarded here also, and the combustion chamber built out in front of the boiler, two courses of fire-brick and two of red brick, the top being of arch fire-tile. The advantage of this method of setting is that the high heat of the combustion chamber secures perfect consumption of the oil at the front end, shortens the flame, and does away with burning the rear head, while at the same time the heat-storage capacity of the combustion chamber is comparatively small, and the fire susceptible of close regulation. With either of the above settings a burner with round nozzle, or other tip throwing a narrow flame, would be used, in order to minimize the burning of side walls of combustion tunnel or box. With this provision, any form of burner would be applicable.

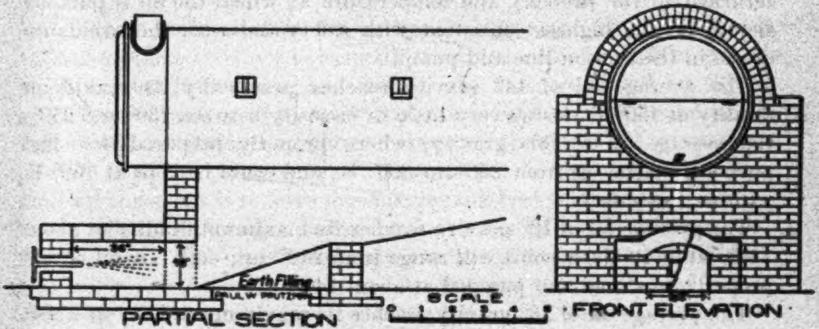


Fig. 61. Tunnel Setting, Front Fired.

There is undoubtedly great room for improvement in the matter of setting horizontal boilers for oil burning, as the systems most used at present are admitted to be highly unsatisfactory. When the price of fuel oil rises, as it undoubtedly will in time, engineers will be forced to figure more closely as to the efficiency of the oil plant, and when this is done a radical alteration in present methods may be looked for.

CHAPTER 8.

STORAGE AND HEATING.

Temperature.—The temperature at which oil is passed into the burner will depend largely on the character of oil used, as to its viscosity and flash point. If the oil is to be heated at all in the tank, it is desirable to heat to such temperature as will render the oil fluid, to permit of handling with reasonable steam consumption at the pump; on the other hand, it is not desirable, for several reasons, to heat the oil beyond its flash point, and as a rule that point should not be approached too closely. The temperature between the discharge end of the fuel pump and the burner is, however, much less important than that between the suction end and the storage tank.

In some cities there are insurance or fire regulations which prevent the heating of fuel-oil tanks, but in many situations where oil is used for fuel there are no requirements except such as the consumer sets for his own safety. The steam required to keep a fuel supply at a moderately high temperature being considerably less than that required to pump the same oil cold (owing to the heat being, in the first case, largely returned to the firebox), the temperature at which the oil is pumped should be the highest consistent with safety and with the avoidance of gas in the suction line and pump.

The average oil of 14° gravity reaches practically its maximum fluidity at 150° F., losing very little in viscosity between 150° and 250°; the average oil of this gravity, where properly prepared for fuel purposes, flashes at from 250° to 300° F., and could be kept at 150° F. with perfect safety.

The average oil of 16° gravity reaches its maximum fluidity at about 140°, while its flash point will range from 240° up; such an oil would properly be stored and pumped at about 140°.

The average oil of 18° gravity reaches its maximum fluidity at about 110° F., while the flash point would be 175° or above; such an oil should be kept at about 110°.

The average oil of 20° to 22° gravity is usually sufficiently fluid at ordinary temperatures. Its flash point will range from 130° up to 180°, and it may be heated, if necessary, to 100° with safety, but not higher unless the flash point of the particular oil were known.

Oils lighter than 22° are rarely used for fuel purposes, being of more value in other ways.

Distillates are used for fuel in some cases, being particularly easy to handle in some situations where there is difficulty with heavy crude; for instance, where very small flames are required. The flash point varies from below normal to as high as 200° F., but the average fuel distillate, of 25° to 27° gravity, should flash at from 130° to 180°. Where fuel distillate is to be handled in any quantity, its flash point should always be taken, either by producer or consumer, as it is very liable to fluctuation. It is rarely necessary to heat distillate used for fuel.

Gas.—It has been contended that heating a heavy oil in the tank, or between the tank and the pump, increases the liability to gas trapping in the suction, and this is undoubtedly true under some circumstances. But it should also be borne in mind that the giving off of gas from a crude oil is greatly facilitated by reduction of pressure; that is, if the oil is rendered fluid, so that the vacuum in the suction pipe is low, the amount of gas given off may be less than if the oil is cold, making the vacuum in the suction pipe much higher. The question as to which condition is most favorable to the avoidance of gas will depend for its answer on the nature of the oil, and the size and length of the suction; there will necessarily be great difference in different cases.

The formation of gas in both suction and discharge ends, but particularly in the suction, is one of the most annoying difficulties encountered in handling crude oil. In many cases it can not be avoided by any practicable arrangement, but much trouble can often be obviated if, in installing a fuel-oil plant, attention be paid to the kind of oil to be handled.

If the oil to be used is 18° or lighter, the arrangement of pump and connections need not be very different from what would be put in for water; but if the oil is, as is usually the case, to be 14° to 16° in gravity, great care must be taken with tank and suction connections. It goes without saying that the storage tank should be set as close as possible to the oil pump, and as nearly as possible on its level. The ideal arrangement is to have the storage tank feed the pump by gravity, but in cities, or where the danger of fire is considerable, this is out of the question. But it is absolutely necessary to keep the lift within reasonable limits, for if the oil is to be pumped cold, it is hardly possible ever to lift more than six or seven feet in cool weather, while even with a four-foot lift it will be difficult at times to make the pump take up heavy oil. For this reason, and as the gas in the discharge may be bled off, which can not be done in the suction, the pump should be kept as low as possible, preferably on the boiler-room floor, even at the expense of some inconvenience in cleaning, etc. The suction pipe should be large; if cold oil is to be pumped it should have not less than twice the area of the discharge, and where the trail is long this suction area can be considerably exceeded. The drawback to large suctions is in first cost only; once installed they cost no more than a smaller pipe, and the difference in first cost will soon be balanced by saving in time and repairs. Where the suction has two or more bends they should, if possible, be made with pipe bent to a long radius, or where this is impracticable, with long sweep ells, while any unnecessary fittings on the suction should be carefully avoided.

Size of Pump.—As to size of pump required to handle any quantity of oil, a great deal will depend on the quality of the oil. A pump will handle very nearly as much oil of 18° or lighter as of water, whether the oil is hot or cold, but where 14° oil is to be pumped cold the water end should have at least five times the cubic capacity required for an equal delivery of water. In pumping cold heavy oil it is necessary to reduce the piston speed much below what would be good practice in pumping water, while even with light or hot oil it is not desirable to speed a pump very high. The valves in the water end, where seated by springs, should be set at the lowest tension consistent with prompt seating. A small amount of slip through the valves because of slow seating is better than continual trouble with gas binding in the cylinders. Owing to the high compressibility of oil gases, they are slow to lift the valves when the latter are heavily weighted, and it is no uncommon sight to see an oil pump alternately compressing and distending the gases in both ends of the cylinder, without the valves lifting from their seats.

In regard to the size of steam end, it is impossible to give any rules from the data so far worked out. It is probable that with low pressures (twenty to thirty pounds) an oil of 14° gravity offers from three to four times the resistance in the pump which would be given by water, but only where the oil is being circulated very slowly, as is usually the case in a fuel-supply system. The resistance to flow through pipes rises very rapidly as the speed is increased, much more rapidly than with water or other light liquids. Where the oil goes from the discharge immediately to the heater, and is carried in the discharge system at 150° or above, the resistance offered to its flow through the pipes is not much greater than that of water.

Pressure.—The pressure at which the oil is carried to the burners is a matter of opinion. It is probable that moderately high pressures (forty to sixty pounds) assist in atomizing, and lower the steam consumption at the burner more than enough to make up for the extra steam consumed at the pump. There is very little doubt that more oil can be burned under a boiler with high oil pressure than with low, and where boilers are being forced to their maximum capacity this is a material advantage. But on small plants, where boiler capacity is usually sufficient, this is of less importance than the difficulty of making tight joints with hot oil under high pressure. High pressures, particularly if carried on the oil orifice of the burner rather than on the needle valve, serve to prevent choking up.

Gravity Feed.—For small plants, where insurance regulations do not figure, gravity feed has several advantages. The great drawback to this system—the danger in case of fire—does not amount to much if the tank is set at some distance from the buildings, and on a foundation which can not burn out. As with gravity feed it is rarely possible to get more than eight or ten pounds pressure at the burner, there should be provision for keeping the oil very hot, the burner should be of some form which will work to satisfaction at five pounds oil pressure, and traps or siphons in the feed pipe must be avoided. Gravity feed is not at all economical of steam, as the saving in pumping is more than compensated by the extra steam required to inject low-pressure oil, but it has the great advantage that it is independent of steam or solid fuel for starting (a layer of brickbats or other non-combustible material, saturated with oil, providing a means of starting up a small boiler) and that gravity is much more dependable than a small feed pump.

Piping.—Two recognized methods for bringing oil to the burners are used: the circulating system and the "dead end" system. In the first, more oil is pumped into the feed pipes than the burners consume, the excess being taken from a point near the burners, through a pressure regulator or standpipe, back to the suction of the pump. In the second, there is no outlet for the oil, even pressure being maintained by proportioning the steam end of pump to steam and oil pressures; it is apparent that this would work only where boiler pressure remained constant, but governors are also in use which regulate the steam supply to pump, according to pressure on oil system. The first method has the advantages: first, that even pressure is maintained independent of fluctuations in steam pressure or in temperature of oil; and second, that the constant flow of oil through the pipes tends to prevent their being stopped up by sediment deposited from hot oil. A third point, sometimes of much importance, is that the quantity of oil passing through the heater, being independent of quantity used, is much more constant than where it varies with the adjustment of burners, and thus the temperature of oil issuing from heater is much more likely to be constant. This is a material advantage, for where there is much fluctuation in the temperature of the oil brought to burners, the quantity fed through a valve set at a certain point will also vary greatly, and thus disturb the relative adjustment of steam and oil, and require more attention from the fireman. Of course, in circulating the oil there is some loss of power, but the quantity of steam required by the oil pump is a very small matter, at most, compared with the steam consumed in the burners.

There is one material disadvantage attached to this system: that the gas, more or less of which is always carried into the pipes from heater, is turned back into the pump suction. If conditions are such that the returned oil can be carried to the storage tank, this does not figure, but it should be borne in mind that even where the quantity of oil circulated is but little more than the burners use, the constant return of hot oil to the tank will, if the latter be small, raise its temperature considerably in the course of a day's run. In some cases, where it is desired to carry the storage tank hot, this method is used for heating the stored oil, instead of putting coils in the tank itself.

Heaters.—The heater should of course be at the discharge end of the pump, and is best arranged so that oil and steam flow in opposite directions. It is desirable that the oil should move from bottom to top, and there should be considerable space below the inlet to allow dirt to settle on the bottom, where a plug is provided for cleaning from time to time. Space should also be left above the tubes for gas, and a bleeder or other device placed on the crown so that the gas may be removed, while oil is taken from the side, two or three inches from the top. This arrangement separates gas from the oil, and keeps it out of the pipe system, thus helping to avoid the blowing out of burners by gas bubbles. A simple petcock for bleeding off the gas requires a good deal of attention, and where the quantity of oil handled is large, it may be economy to use an automatic bleeder, similar in construction to the air bleeders used on water pipe-lines.

This contrivance is roughly sketched in Fig. 16, where it is shown in place in the top of a column heater, though it could be applied as well to any other form of heater having a gas chamber on top. The inner and outer shells of heater are held in position by the 1" pipe, inside of which is passed a piece of ¾" XX pipe, bored out to ⅜", held below by the valve seat D, above by the faced lock nut E, with rubber gasket, bearing on flange of outer shell. The float A moves the stem B, carrying the valve C. The stem makes a neat sliding fit in the hole through seat D, and in the ¾" pipe; the valve is ground into seat after setting up entire apparatus. The stem is supported above by a nut F, which carries the weights, and is channeled lightly on four sides, the channels being carried below bottom of thread where stem passes through nut. The length of stem is so adjusted that the float will be about half submerged when the oil in inner chamber is at the desired height above outlet. By placing ordinary iron scale weights over top of stem, the buoyancy of float and gas pressure on stem are exactly balanced. As gas accumulates in top of heater the oil will be forced down, the float will fall, carrying valve away from seat, gas will escape through the grooves in stem, and the oil rising to balance pressure will raise the float, closing valve. The entire play of the stem need not exceed ⅛", as the rise and fall of stem when in use are almost imperceptible.

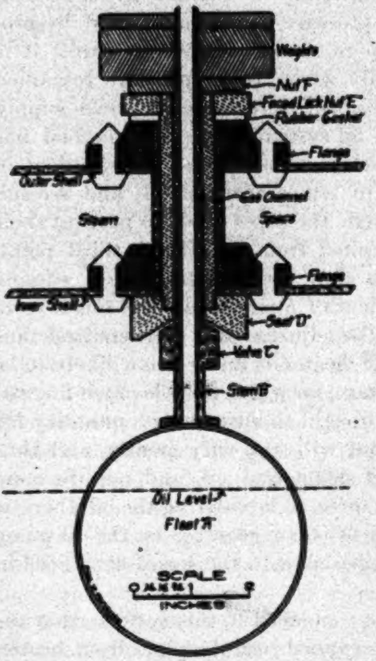


Fig. 16. Automatic Gas Relief Valve.

This contrivance is sensitive and reliable, as there are no packed joints to gum, and sticking of stem or valve may be relieved by running light mineral oil into grooves, and revolving stem. The cost of the apparatus is considerable, and its use is hardly justified unless considerable quantities of oil are being handled.

Probably the best arrangement for a heater, though a rather expensive one, is a battery of small tubes, connecting chambers above and below, and jacketed for steam outside. (See Fig. 17.) The tubes should have a combined area somewhat larger than that of the outlet pipe; the length is figured from the heating surface required, and this from the temperatures and the amount of oil passed. In figuring on the basis of heating an equal amount of water, allowance must be made for the fact that with oil, while the specific heat (that is, the heat required to raise a given amount of oil to a given temperature) is less than with water, the speed of absorption and transference of heat through oil is very low. This makes a larger heating surface necessary than would be required for water under the same conditions, but there are not, so far as the writer knows, any figures to be had which will determine how large this allowance should be. A heater of ample size is an excellent investment.

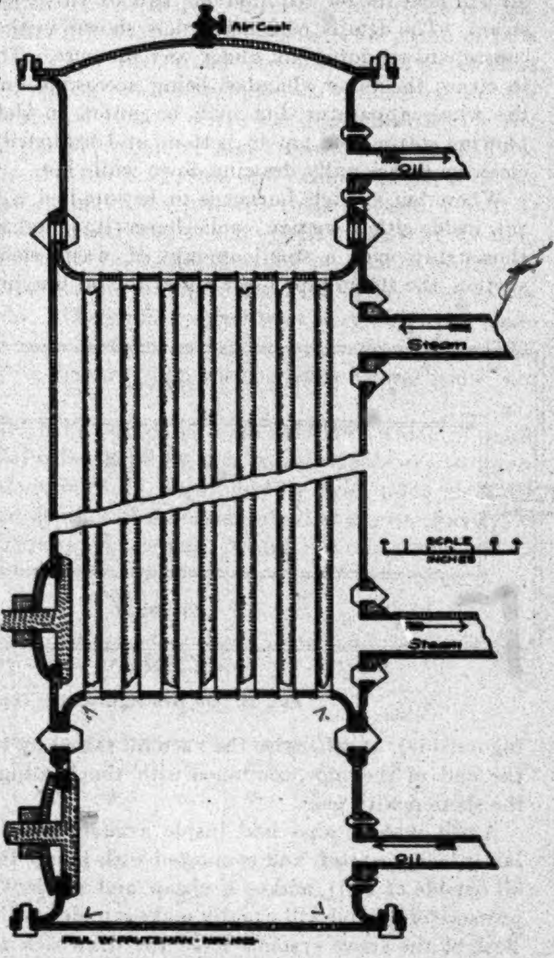


FIG. 17. Oil Heater, Tubular Pattern.

The chamber heater (see Fig. 18) is a cheap device, which takes up much room in proportion to its capacity, but otherwise gives good results. If made of 6" pipe inside 12" casing, a length of five feet over all will heat the oil required for two or three burners, using exhaust steam. The details of construction shown in the figure would not, of course, answer for steam under any pressure. This heater is difficult to clean, the inner chamber being accessible only by breaking down the whole apparatus, but may be gotten in shape, if very dirty, by blowing steam from top to bottom, and ordinarily may be kept fairly clean by occasionally drawing down while hot.

Where but a single burner is to be supplied, a $\frac{1}{4}$" steam pipe may be run inside either suction or discharge line, and will heat the oil very thoroughly with a small amount of waste steam. If placed in the suction, the steam pipe must follow the oil line into the tank (discharging outside), as otherwise the vacuum raised by the plug of cold oil in the end of the pipe, combined with the heating of the oil, would fill the suction with gas.

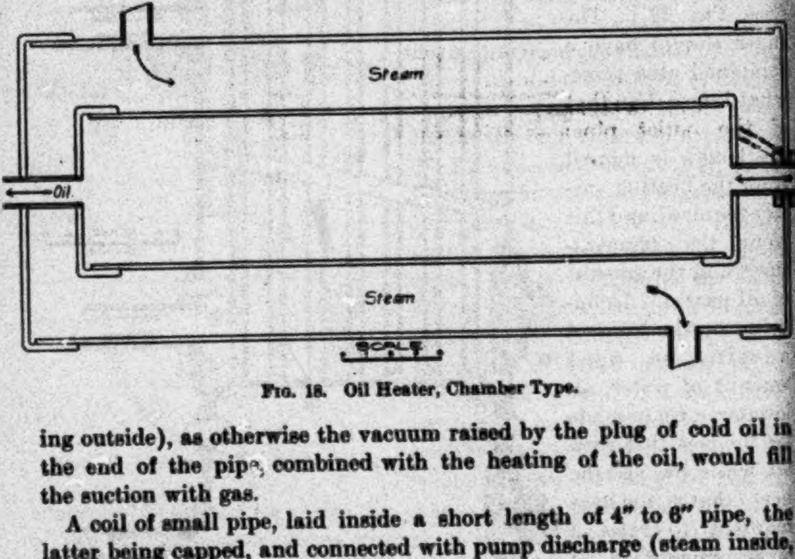


FIG. 18. Oil Heater, Chamber Type.

A coil of small pipe, laid inside a short length of 4" to 6" pipe, the latter being capped, and connected with pump discharge (steam inside, oil outside of coil), makes a cheap and efficient heater, but the back pressure of the coil will usually make it undesirable to use exhaust steam. Both of the above systems have the drawback that they do not tak care of the inevitable gas, but pass it to the burner. Suitable heatin arrangements of simple form, adapted to the particular case, wil readily suggest themselves to the engineer.

Some users of oil prefer to take it to the burner cold, but the difficulty of pumping, and even more, of regulating cold heavy oil, woul seem to make it desirable to heat the oil wherever possible. A heate of ample capacity has a strong cleansing effect on the oil, depositin sand and water, and causing the sludge to be taken up by the oil, and while this may be of little importance so long as the oil comes to the tank clean, it is very useful if the oil is bad, as will occasionally happen.

Pressure Regulation.—The pressure in a circulating system is regulated either by a pressure relief valve such as is used for water, or by a standpipe with overflow. For the former use, a standard water relief valve, operated by a spring, and adjustable with wheel, is on the market. If a relief valve is needed where the regular article is not obtainable, a very satisfactory regulator may be made from an old globe valve, by removing the threads from stem, and putting in place of the wheel a broad iron disc, to be loaded with the proper weight. As it is necessary in doing this to exactly center the weight, to prevent the stem binding in the packing, it is sometimes thought preferable to remove the wheel and fit a lever resting on top of stem (as in the lever safety valve) with ball weight. These relief valves work very well when made with care, and an old valve answers as well or better than a new one; it seems unnecessary to remark that the pressure comes below, not above, the disc.

In regulating pressure by standpipe and overflow, which is more reliable than any relief valve could be, it is merely necessary to figure the height required above burner. The following brief table gives the height (in inches and tenths) of a column of oil of known gravity, at known temperature, required for a gauge pressure of one pound:

TABLE 10.

		Temperature of Column, in Degrees Fahrenheit.							
		60°	70°	80°	90°	100°	110°	120°	
Gravity of Oil, in Degrees Beaumé.	10°	27.7	27.8	27.9	28.0	28.2	28.3	28.4	Height of Column required to give 1 pound gauge pressure, in inches and tenths.
	11°	27.9	28.0	28.1	28.2	28.4	28.5	28.6	
	12°	28.1	28.2	28.3	28.4	28.6	28.7	28.8	
	13°	28.3	28.4	28.5	28.6	28.8	28.9	29.0	
	14°	28.5	28.6	28.7	28.8	29.0	29.1	29.2	
	15°	28.7	28.8	28.9	29.0	29.2	29.3	29.4	
	16°	28.9	29.0	29.1	29.2	29.4	29.5	29.6	
	17°	29.1	29.2	29.3	29.4	29.6	29.7	29.8	
	18°	29.3	29.4	29.5	29.6	29.8	29.9	30.0	
	19°	29.5	29.6	29.7	29.9	30.0	30.1	30.2	
	20°	29.7	29.8	29.9	30.1	30.2	30.3	30.4	

Connections.—The accompanying sketches (Figs. 30 and 31) show connections and pipe arrangements between the tank and boiler front. The order of these connections is apparent enough without any description. The pipes are all small, unless a large number of burners is to be supplied, as a single burner is amply taken care of by ½" oil pipe and ¾" steam pipe. It is always well to have a cock in the oil pipe back of the main valve controlling the burner supply, and to have a stop in a handy situation on the main oil feed, so that all the burners may be shut down at once in case of accident.

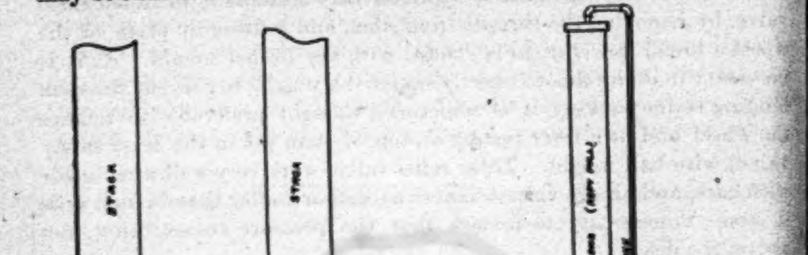


FIG. 30. Oil Burners, Front End Connections.

The valve controlling burner oil supply must be very sensitive, and i always likely to choke. Needle valves are often used, though stopcock are sometimes preferred. If the latter are used, they should be of th lever-handle variety, and work rather stiff. They may be made mu more sensitive by stopping up the opening in the plug, and drilli through the latter, at right angles to the opening, a hole ⅛" in diamete Or with less trouble, one face of the opening in plug may be widene with a file, say $\frac{1}{32}$" above its original size, while at one side of the oth face a V-shaped cut is made with a small file. Either of these arrangments offers a very small opening to the first passage of oil, while with the second the valve may be thrown wide open if desired.

Impurities in Oil.—Oils lighter than 18° in gravity are generally almost free from water and sediment, but heavier oils sometimes contain notable quantities of both, though a great change for the better in that respect has been made of late. Both impurities are very objectionable. Water not only displaces its own bulk of oil, but also lowers the total evaporation by its own weight or more; the principal objection, however, is due to its tendency to emulsify with the oil, forming a froth which is difficult to pump, and which is likely to form a layer in the tank, practically non-combustible when pumped to the burner. This is particularly true in circulating systems where the excess oil is returned to the service tank, as any water is here in a short time thoroughly churned up with the oil. The writer once saw thirty barrels of heavy oil so completely emulsified with water as to form a pasty mass, which could not be forced through the needle valve, wide open, for more than a minute at a time, with thirty pounds pressure. The paste was so thick as to suggest a large amount of sand, yet a test showed nothing to be present but oil and water. The latter was put into the tank

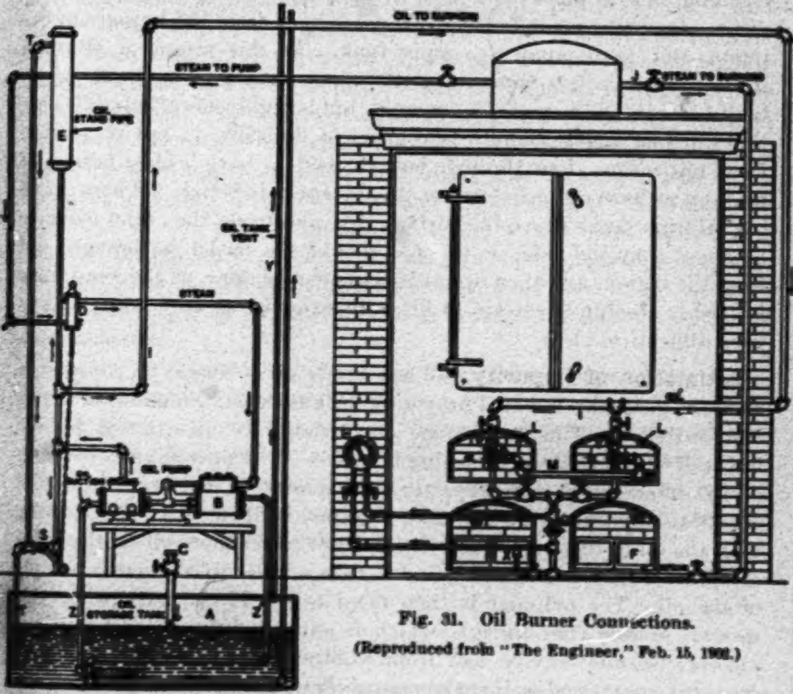


Fig. 31. Oil Burner Connections.

(Reproduced from "The Engineer," Feb. 15, 1902.)

accidentally, was about half the bulk of the oil, and had been thoroughly agitated with the oil before its presence became known. Such a case as this is extreme, yet in many cases difficulty in making burners feed properly may be traced to the presence in oil of a small percentage of water in a finely divided state.

Sand or other dirt is even worse, as when once packed it can not be forced through burners or valves by any amount of pressure, and as it rapidly settles to a hard mass when allowed to stand. Tanks in which oil is to be heated should always be provided with means for cleaning, sags in pipes should be avoided as far as possible, and provision should be made for blowing steam back from the burners to the pump, and from pump to supply tank. As this means of cleaning throws more or less water into the oil, it should be used only when tank is empty, or in case of emergency, but is highly efficacious. Where tanks are set underground it is considered desirable to put in suction from top rather than through bottom, and to have it clear bottom of tank by at least an inch—two or three inches are better. Where drawing oil from tanks above the surface, it is well to set the outlet three or four inches up the side; in no case should the outlet be brought out from the bottom and then up, as is occasionally done, as the bend thus formed is absolutely certain to fill with sand in a short time, and is very difficult to clear.

Estimation of Impurity.—When crude oil is bought on contract, a clause is generally inserted providing for a maximum amount of water and sediment. This percentage may readily be ascertained by the buyer, if desired, in the following manner: A stoppered glass cylinder of 100 cubic centimeters capacity (which may be had from dealers in chemical apparatus for less than a dollar) is filled to the 50 c.c. mark with the oil to be tested, being careful not to get more oil on the sides of cylinder than is necessary, and to take a well-mixed average sample of the oil. The cylinder is then filled to the 75 c.c. mark with commercial *benzole* (not benzine, which is entirely different and will not answer; benzole may be had from wholesale druggists at about fifty cents per quart) and well shaken, until the oil is dissolved off sides and bottom; this can be readily seen by the darker color of the undissolved oil. The stopper is then removed, and the cylinder filled to the 100 c.c. mark with ordinary gasoline, stoppered, well shaken, and allowed to stand for twenty-four hours. At the end of this time the water and dirt, if any be present, will have settled in a clean layer on the bottom, and can be read off, each 1 c.c. of this bottom layer representing 2% of foreign matter in the oil. The cylinder should not be handled until after the reading is made, for if disturbed the bottom layer may be again mixed with the oil above. This method is accurate to one half of one per cent, after reasonable practice, and requires but a few minutes, aside from the time allowed for settlement.

Gasoline Test.—The figures obtained in this manner do not correspond with those given by the ordinary gasoline test, the percentage given by the latter being higher. But there is no question that the usual gasoline cut is, when applied to California oils, inaccurate, and unfair to the producer, for the following reason: Gasoline of 74° gravity, when mixed with heavy crude oil, separates not only sand and water, but also a flaky black or brown substance commonly called sludge. The sludge precipitated in this manner is really asphaltene, a solid substance, which normally remains dissolved in oil, but which is separated by the gasoline in a spongy form, at least eighty per cent of the bulk of the sludge as it settled out in the gasoline cut consisting of gasoline. Asphaltene is an integral part of the oil, will not separate under normal conditions, and has practically the same value for fuel as any other part of the oil. There seems no reason why this substance should be arbitrarily separated and classed as an impurity, nor why its bulk should be read under conditions which give a much greater percentage than the true one. Further, the percentage of impurity determined in this manner, on any one sample, will vary widely with slight differences in the gravity of gasoline used, and with the temperature at which the test is made. The gasoline test as commonly used in the oil fields gives a reading from two to six times as great as the true percentage of foreign matter.

The test with benzole, above outlined, is by no means a perfect one, as the reading of small quantities in a comparatively wide graduate can never be very accurate, and as the water sticking to the sides of graduate is not included in the reading. It is, however, much more reliable and nearer the truth than the common gasoline cut, and is probably as accurate as any process which can be conducted by unskilled persons without laboratory facilities.

CHAPTER 9.

REGULATION OF OIL FIRES.

The proper regulation of an oil fire is learned by experience, and by experience only. But the regulation of draft is a matter of much importance, and a few words on this subject may not be out of place.

Quantity of Air.—The quantity of air required for the complete combustion of a pound of oil does not vary much with various grades of oil (ranging from 170 to 175 cubic feet per pound of dry oil), but the amount actually used in different cases does vary enormously. If the excess of air can be restricted to three fourths of the amount required (making total consumption approximate 300 feet per pound), the apparatus and regulation are probably as perfect as there is any reason to expect, under the best conditions. But where the excess amounts to two or three times the amount used, the waste is very great, and should be corrected.

An oil-burning furnace always works under forced draft, the jet of steam from the burner being a powerful injector. For this reason the draft openings should always be considerably smaller than would be used with solid fuel. Air should be taken into the firebox, in most cases, both at ground level and at a higher point, at or near level of burner. With draft openings of a fixed size, the amount of air passing into the firebox will vary with the amount of steam issuing from burner, and to this extent the draft is self-regulating, but by careful manipulation of draft openings the fireman can almost always improve the efficiency of the firebox. Unfortunately, there is no direct way of telling when the point of greatest efficiency has been reached, without analysis of chimney gases; but by balancing steam against air until the smallest draft opening is found which will keep the fire clear, a fair degree of economy can always be had.

An over-supply of air to an oil fire not only wastes fuel, but also causes a tendency to puffing, particularly with low fires. This may often, though not always, be better corrected by reducing the draft than by turning down the steam supply to burner. When a burner puffs persistently at a point where it should carry a clean fire, it is good proof that the burner does not atomize properly. Some burners, particularly home-made ones, have a space just inside the nozzle where oil might collect in a little pool. When running hard the velocity of steam will carry out this oil as it runs down, but when running with a low fire the oil will collect, finally be blown out in a spurt, then collect again, causing strong puffing of the fire. This can be done away with only by altering the shape of the burner. When burners are expected to run regularly on a small steam supply, they should be so designed that oil entering them will run out clean and freely without the assistance of the steam.

Explosions.—Any trap of this sort will occasionally cause an explosion in the firebox, which may be dangerous under some conditions. Explosions are more often caused by a temporary stoppage of the oil supply through grit, gas, or a globule of water; the oil being suddenly turned again into the hot furnace, often in quantity, will be gasified and ignited by the hot brickwork. These explosions can never be entirely prevented, but may be reduced in number by care in keeping pipes clean, by bleeding off gas, by preventing gas traps and pockets, and by running with fairly high pressure on the oil feed. Serious accidents from this cause are very rare.

Carbon Deposits are due to imperfect atomization, or to improper setting of burners in the furnace. A burner should be chosen to throw a flame of length suitable to the length of the furnace; a long flame in a long and narrow furnace, a short flame in a short furnace. The most prolific source of carbon deposits is improper working of the burner, and this can be corrected only by increasing the steam supply, restricting the area of nozzle, or more often by entire change in form of burner. It is poor economy to shut off incipient carbon formations by increasing the draft—the remedy is worse than the disease. Burners set into a furnace at an angle are sometimes set too close to the opposite wall, and in this case they can be turned, or better, the nozzle so adjusted as to throw a shorter flame. In adjusting a burner into the firebox, it should be remembered that, to restrict excess of draft, it is best to have the jet from burner meet the main current of entering air at or near a right angle. This greatly promotes mixing of air and oil vapor, but generally involves pointing the burner at a wall or target.

An over-supply of steam, or the use of very wet steam, will sometimes partially extinguish an oil fire, causing it to give off a dense white smoke, of a foul and characteristic odor. This smoke consists principally of unconsumed petroleum gases, and is usually seen only for a moment at a time. Where it is produced often, or for any length of time, it indicates an unusual degree of either inattention or ignorance on the part of the fireman, or else a radical defect in the installation. Too much water in the steam is most likely to be the trouble, and this can be corrected either by slightly superheating, or by the use of proper bleeders. It is rarely possible to dry the steam enough to give really satisfactory results with small burners, unless some superheating device is used.

Superheating is often practiced in large as well as small plants, and in many ways is very desirable. It greatly assists in heating and therefore in atomizing the oil, reduces amount of steam used by burner, and prevents accidents due to fire being extinguished by a gush of water. Special superheaters are sometimes used in large plants, but in small installations a coil of pipe in the firebox answers every purpose. The pipe should be extra or double-extra strong, the fittings inside firebox should be cast, and the pipe should have at least twice the diameter of the steam supply to burner (inside). Valve should be placed between superheater and boiler, not between superheater and burner, and it is well to place a trap in the steam pipe at the point where it enters the coil, with bleeder at the bottom. If so set that the flame does not strike coil directly, it will last for some time, and the cost of an occasional renewal is unimportant compared with the satisfaction realized from the use of dry steam in the burner.

CHAPTER 10.

LIQUID FUEL IN LOCOMOTIVES.

This chapter is slightly abridged from a report to the State Mining Bureau by Mr. O. S. Breese.

The use of petroleum as fuel for locomotives involves a number of variations from established principles. The work is very heavy, that is, a large amount of oil must be burned in a small firebox; the demand for steam varies enormously, and the system must be flexible enough to meet these variations without excessive waste; and further, provision must be made for carrying a very low fire, or entirely extinguishing it, for several minutes at a time, during stops.

The first attempt to meet these difficulties was made with various appliances for vaporizing the oil in separate apparatus, it being thought that in a locomotive firebox it would be impossible ever to vaporize the oil by radiant heat. These systems, however, proved so cumbersome and expensive to maintain, that very little advance was made along such lines, and it was not until the invention of the combustion-chamber firebox, about the year 1882, that the use of liquid fuel on locomotives became a practical possibility. This invention is credited to a Scotchman, Thomas Urquhart, who was Superintendent of Motive Power on the Garzi-Tsaritzin Railroad, in southeastern Russia, from 1881 to 1884.

The Combustion Chamber, which now forms the basis of the ordinary system for burning petroleum in locomotives, consists essentially of a fire-brick box supported by the ashpan (the grate bars being removed), the flame of the burner entering at the front, and the fire gases passing out, and into the firebox proper, through checker work or other suitable openings in the top. The object of this combustion chamber hardly needs explanation. It is well known, of course, that oil must be vaporized before it enters into combination with air, and this vaporization is effected by radiant heat from the brick walls surrounding the flame. The higher this heat, the more readily and quickly will the oil be vaporized, and the more complete and controllable the combustion. The combustion chamber, being of comparatively small size, and out of contact with the water legs of the boiler, reaches a much higher heat than it would be either possible or desirable to bring the entire firebox to, thus vaporizing the oil rapidly and completely, avoiding smoke or waste, and making it possible to regulate the fires very closely. Further, by storing up considerable quantities of heat (by reason of its high temperature) it enables the fire to be turned very low without going out, a difficult matter in a large firebox, or even to be turned completely out for several minutes, and restarted by simply

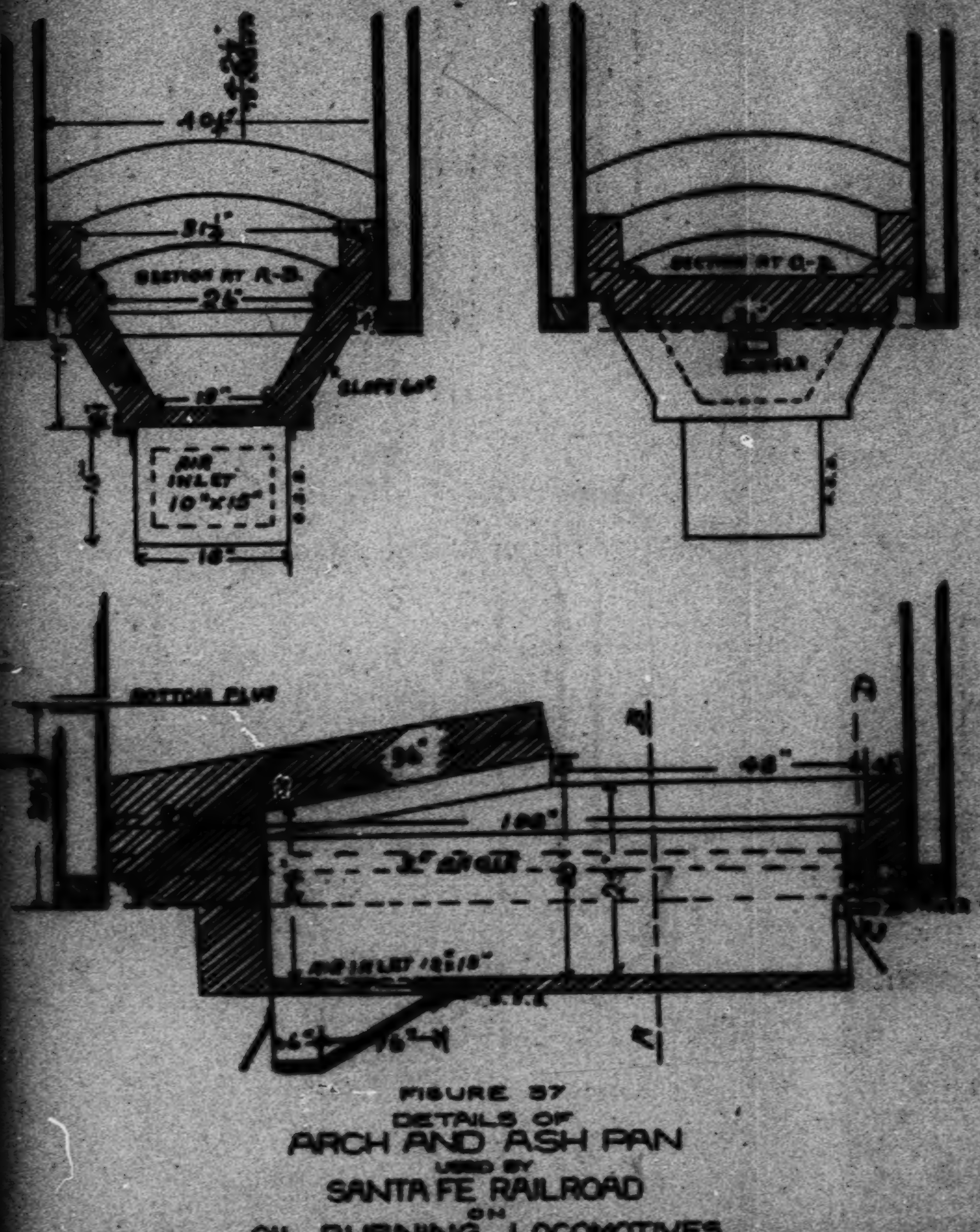

40½"
31½"
SECTION AT A-B.
26"
19"
SLOPE 60°
AIR INLET 10"x15"
18"
15"
SECTION AT C-D.
BOTTOM FLUE
36"
48"
108"
AIR INLET
A
B
C
D

FIGURE 37
DETAILS OF
ARCH AND ASH PAN
USED BY
SANTA FE RAILROAD
ON
OIL BURNING LOCOMOTIVES

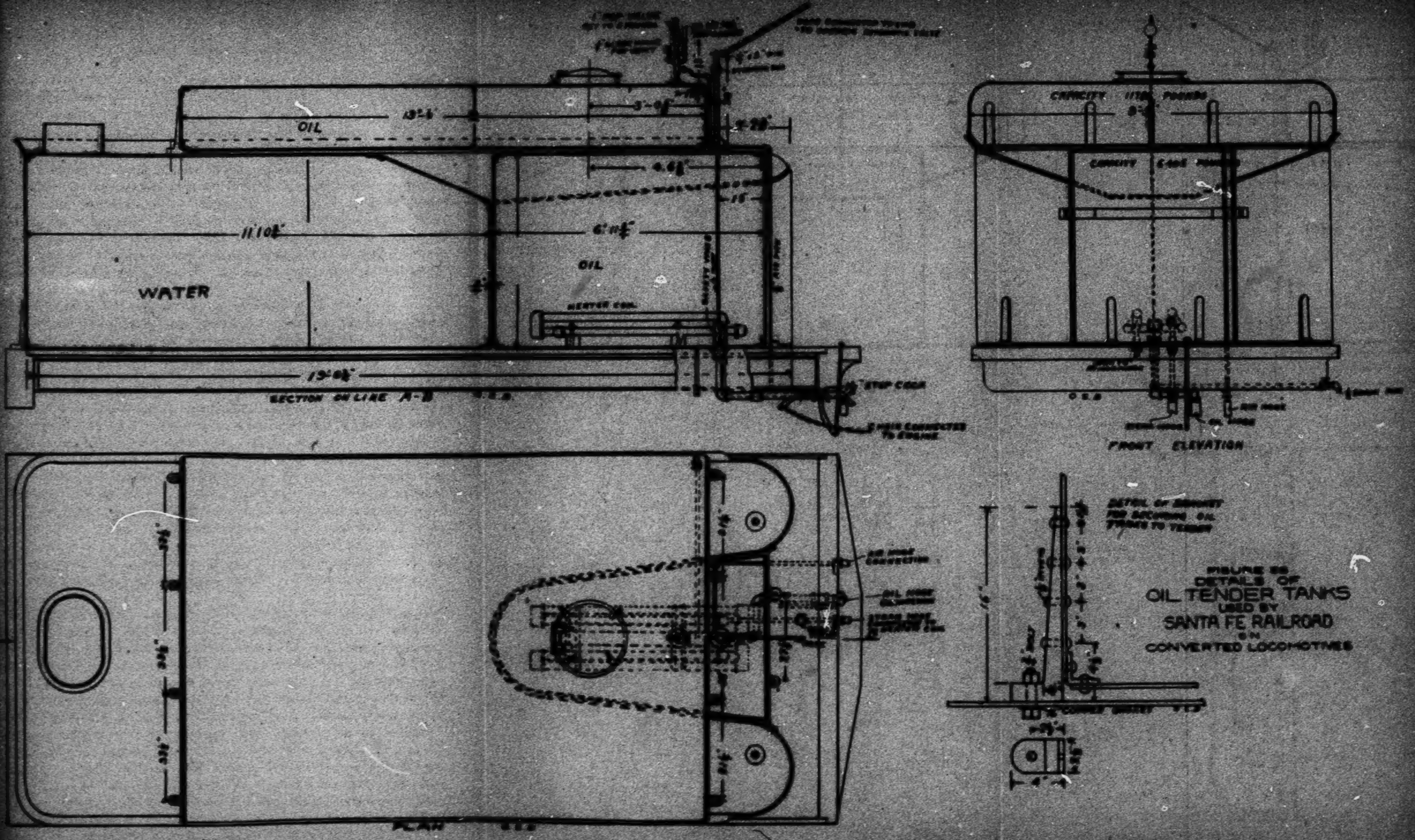

OIL
13'-6"
3'-9½"
2'-2½"
4'-6⅝"
15"
11'-10½"
6'-11⅝"
WATER
OIL
HEATER COIL
19'-0½"
SECTION ON LINE A-B
STOP COCK
HOSE CONNECTED TO ENGINE
CAPACITY 1170 POUNDS
CAPACITY 6405 POUNDS
FRONT ELEVATION
AIR HOSE CONNECTION
OIL HOSE CONNECTION
PLAN
DETAIL OF BRACKET FOR SECURING OIL TANKS TO TENDER
COPPER GASKET

FIGURE 55
DETAILS OF
OIL TENDER TANKS
USED BY
SANTA FE RAILROAD
ON
CONVERTED LOCOMOTIVES

turning on the oil. It should be said, however, that turning out fire at stops is very hard on flues and firebox sheets, and is not countenanced by many superintendents.

To Convert a Coal-Burning Engine into an Oil-Burner, it is necessary first to remove the grates and grate-frame, then to fit inside the ashpan a suitable casting, riveted to the pan at the sides and near the top. This casting acts as a support for the interior brickwork, and is cored out to admit air to the firebox for combustion. After many experiments a number of methods of admitting the air have been adopted, some taking the air at the rear and sides, others at the front of the ashpan. The one most suitable in any particular case will depend on the construction of the locomotive, very little difference in results being apparent.

A fire-brick arch is constructed just in front of the flues, and should be made as low as may be, the object being to protect the crown sheet, crown bolts, and seams from overheating. (See Fig. 37.) The brickwork, which in operation becomes actually white hot, serves a very important purpose in this scheme, and although it can not be regarded as absolutely essential, since there are systems which do without it, yet there can be no question that much more uniform and reliable results are obtained by its use. When properly constructed of good material, the brickwork will last for six or eight months, but poor brick rapidly break down under the intense heat.

The oil burner should be secured to the bottom of the mud ring (generally), exactly centered, and at such an angle that the jet from the burner will strike just under the arch, as this helps to break up the particles of oil and assists the combustion. The burner should be set far enough back to avoid carbonization, if left turned off in a heated box, and should be so constructed that it may be cleaned while in operation, either by a fixed cleaning needle, or by opening the nose of the burner.

The oil is carried in two tanks (see Fig. 38), one of which is made in "V" shape to fit in the coal space of the tender, and high enough to be flush with the top of the water tank. A second, and larger tank, rectangular in shape, covers both water and lower oil tanks, and is fitted to the latter, with an opening between. The two tanks, or more properly one double tank, have capacity for eight tons of oil, and are firmly anchored to water tank and tank frame, The one manhole is on top of the upper tank, directly over the opening between upper and lower.

For protection against accidents, a safety valve is fitted in outlet to oil tank (*i. e.*, between tank and burner), valve being held open by a spring key. In case of a break-in-two, a cord connected to the cab draws out this key, allowing the valve to close of its own weight, thus shutting off the flow of oil.

When handling heavy oil, it is necessary to heat the oil by means of steam coils, both to get regular feed, and because of the better spraying of warm oil. With such oils it is also necessary to carry a light pressure, up to five pounds, in the tanks, in order to get sufficient feed. With high gravity oil, or during the heated season, neither of these precautions is necessary.

In Firing Up an Oil-Burning Engine in the roundhouse, or where steam is available for spraying, a burning piece of oily waste is thrown into the firebox and the oil valve cracked, the steam valve then being opened far enough to atomize the slight flow of oil, which should ignite instantly, even in a cold firebox. Care should be taken not to start with too large a stream of oil, as in a cold box only a small quantity will burn, and any excess which would run into the pit would be a source of danger later, when the apparatus becomes hot. As soon as the fire is burning freely the door is closed, but the fire should be watched for some time, as until the brickwork is heated a small amount of water, always likely to be present in the tanks, will extinguish the flame. If the firebox was totally cold when this occurred, no indication would be given, but if even moderately hot, the cutting off of the fire would be readily detected by the evil-smelling white fumes rising from the stack. The odor of these fumes, which is highly characteristic, is due to the decomposition of the oil on the heated brick, and is an infallible warning.

Where steam is not available, it is necessary to fire up with wood, and in this case much care should be taken in filling the firebox, as after the arch has been in use for some time it is quite fragile, and easily broken by careless handling of solid fuel. Care should also be taken, when starting off an engine which has been fired up with wood, to see that all unburned wood is removed from the firebox, as, there being no netting to retain sparks, these might be a source of danger to buildings or equipment.

Pieces of brick from walls or arch are likely to fall at any time, and a very small obstruction on floor of combustion chamber will often interfere with proper combustion in an astonishing manner. A light rake or hook should be provided for the removal of such débris. It is often the case, particularly where oils are dirty or very heavy, that a deposit of carbon will form in the axis of the flame, generally in a cone shape, building out from whatever walls happen to be in line. This deposit is due to incomplete vaporization of the oil (see page 71) and is the fault of the burner, which may be choked, warped, or improperly adjusted. When this happens, the only remedy available on the road is to remove the carbon as often as possible, but the burner should be looked to as soon as the engine reaches the roundhouse.

In operating an oil-burning engine, it is necessary to use sand to clean the gum from ends and inner surfaces of flues, the sand being applied through an elbow-shaped funnel, made for the purpose, and inserted through an aperture in the fire-door. When the sand is being applied by the fireman, the engineer drops the lever in the corner notch and has the throttle wide open; the remedy is very effective, and needs to be used perhaps three or four times going over a long and hard division.

In handling an oil-burning locomotive on the road, it is necessary for engineer and fireman to work in harmony. That is, the engineer, before closing the throttle, should notify the fireman, in order that the latter may also close the oil valve, thus preventing excessive smoke and waste of oil. In starting, also, the engineer should not open the throttle until the fireman has opened the oil valve, that the fire may be burning before any cold air is drawn into the firebox by the exhaust, and the flow of oil should be gradually increased as the exhaust increases. Care in these respects will greatly reduce leaks around flues, crown sheet rivets, and stay bolts. It is evident that there is the closest relation between the strength of the exhaust and the amount of air drawn into the firebox, but while with a coal burner the fire is always burning, with an oil burner it may be almost or quite cut off, and in this case if the exhaust continues, air will be drawn into a very hot but empty firebox. The effects of such abuse need no comment.

Over-firing is also extremely easy on an oil-burning engine, and will cause great damage in a very short time. When burning coal, if the steam pressure drops back five pounds, it takes some little time to pick it up, but when burning oil it is easy to crowd the fire so as to regain the pressure almost instantly. Where this is done the over-heating of the sheets does much harm, in extreme cases even melting off rivet heads. To get the best results from oil burning, the oil supply should be so regulated as to raise steam at about the same speed as with coal.

Spraying with Air has been extensively tried, both for firing up and for steady running, but no particular advantage has been demonstrated, and the disadvantages are obvious.

The Advantages of Oil Burning are numerous, but may be summed up briefly in the following points:

Economy in cost of fuel; this is very great in this State, but depends of course on comparative prices of coal and oil. It is claimed, on what appears to be good authority, that in practice one pound of average oil will do the work, in a locomotive, of one and three-fourths pounds of average coal. These results have been reached in Russia, but the coal there is notoriously poor. At any rate the factor would be variable, depending on relative fuel values, but it is probable that, as in stationary practice, the actual economy in the use of oil would be greater than would be indicated by the direct relation between calorific values multiplied by prices. The percentage of efficiency attainable in oil burning is almost always greater than can be had, under the same conditions, when burning coal, and this should hold good in locomotive practice.

Ease with which fuel is handled; there is no great saving in direct labor on this score, except in handling fuel in store, as the services of the fireman are as necessary with oil as with coal. But it is a distinct advantage that the fireman is enabled to give his entire attention to holding steam and regulating the fire, instead of putting in a large part of his time in shoveling coal.

Elimination of handling of ashes; both as regards disposal of same at terminals, and in cleaning of ballast.

Perfect regulation; practically doing away with waste of steam from the safety valve, this being one of the principal causes of the greater percentage of efficiency realized in the use of oil.

Reduction in time in turning power; if water tank and oil crane are so spotted that oil and water may be taken on at the same time, there is no reason why an engine should not be turned in from twenty to twenty-five minutes.

Clinkering of engines, at terminals and on the road, is entirely done away with.

Freedom from cinders and sparks; an advantage of more importance, perhaps, than any other. The wear and tear, and necessity for cleaning engines, are much less, the comfort of travelers on passenger runs is immeasurably increased, and last but not least, the very destructive and costly grain and forest fires due to flying sparks are entirely avoided.

Against these advantages must be set the single drawback, that oil firing will, on the average, reduce the life of flue sheets and firebox about twenty-five per cent. Where crews accustomed to firing with coal are first given charge of oil burners, the damage may be greater for a time, but when the necessary precautions are once learned, as they readily and rapidly will be, this figure should not be exceeded.

Mr. H. M. Honn, at one time Traveling Fireman of the Southern Pacific Railroad, San Joaquin Division, writes the following interesting letter, inclosing sketches reproduced herewith:

"The sketches, which I think will be clear, are made from Engine "No. 1450, which has been burning oil since the 20th of November, "1901. And here let me say that this engine has been pulling the Owl "train (a limited) ever since her equipment with oil, between Kern "City and Mendota, California, a distance of one hundred and forty-"four miles, which she doubles every day. She has never lost her turn "out, nor a minute's time on the road, on account of oil fuel.

"In equipping an engine for oil fuel (on the Southern Pacific) the "grates are removed, and a pan called the inner-pan substituted.

"This is bolted to side sheets at about the same place as grates were, "and extends about 6" or 8" below foundation ring, or position of "burner. This pan supports side walls and arches, and is covered with "fire-brick, except at air inlets K and L. (See Fig. 33.)

"It will be noticed that the box is walled up all round to about the "height of the arch. In the case of a firebox seven feet or more long, "the front wall is placed back a distance from the flue sheet. This is "for the purpose of throwing a flame to the back of crown sheet, thus "getting the use of entire heating surface. The arrangement of walls "and arches gives almost an entire firebox of fire-brick, which come to "a white heat, to spray the oil into.

"But very little change is made in the front end arrangements, "except that no netting is used.

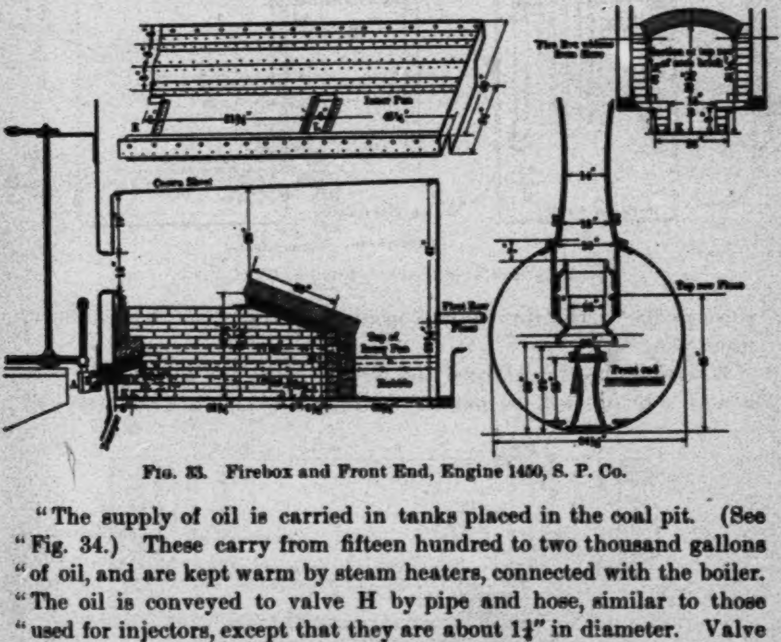


FIG. 33. Firebox and Front End, Engine 1450, S. P. Co.

"The supply of oil is carried in tanks placed in the coal pit. (See "Fig. 34.) These carry from fifteen hundred to two thousand gallons "of oil, and are kept warm by steam heaters, connected with the boiler. "The oil is conveyed to valve H by pipe and hose, similar to those "used for injectors, except that they are about 1¼" in diameter. Valve "H is an ordinary stopcock, and controls admission of oil to burner "and firebox. Atmospheric air is admitted to oil pipe at I, and passes "through burner (see Fig. 35) with the oil, which enters the burner at "B, and runs along trough F to point D. Here it meets a steam jet, "admitted to the burner at A, and passes through the burner just "under the oil trough to point D, where it catches the oil and discharges "it into the firebox through the nozzle E. Atmospheric air is also "admitted to burner at C, and is drawn to discharge nozzle by action "of steam jet (called atomizer). The idea of admitting atmospheric "air through the burner is to get it mingled with the gases and vapors "at the particular point where it is most needed. Air is also admitted "through the firebox through the openings K and L in the bottom of "inner-pan.

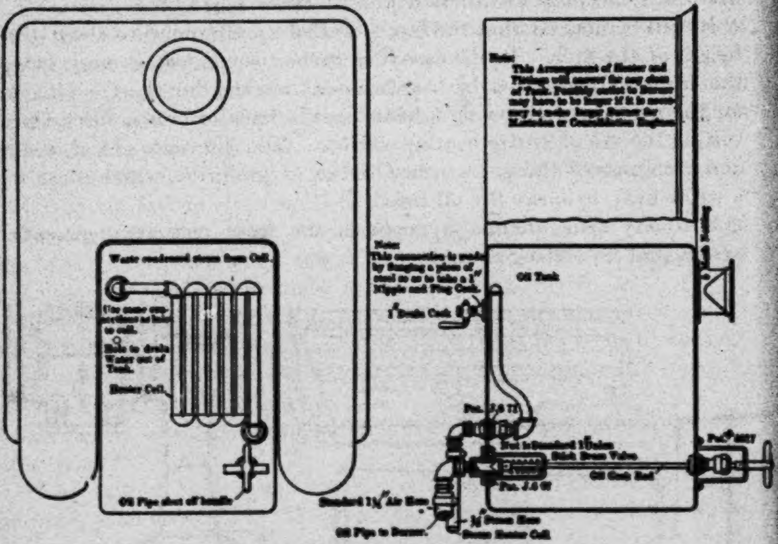

Waste condensed steam from Coil.
Hole to drain Water out of Tank.
Heater Coil.
Oil Pipe shut off handle
Note:
This Arrangement of Heater and Fittings will answer for any class of Tank. Possibly outlet to Burner may have to be larger if it is necessary to make larger Burner for Mastodon or Consolidation Engines.
Note:
This connection is made by flanging a piece of steel so as to take a 1" Nipple and Plug Cock.
1" Drain Cock
Oil Tank
Standard 1¼" Air Hose
Oil Pipe to Burner.
¾" Steam Hose
Steam Heater Coil
Oil Cock Rod

Fig. 34. Tank Arrangement, Engine 1450, S. P. Co.

"When the throttle is closed and the fire being cut down, great care "is needed or fire will be put out entirely, and this is what makes oil "fuel so hard on fireboxes. Going into stations where stops are to be "made, the sheets are expanded with the intense heat, and the careless "fireman, in cutting down his fire, puts it entirely out. Take into con-

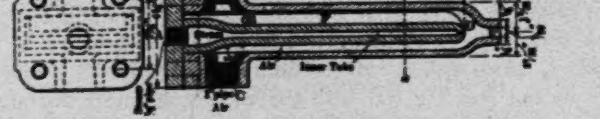

Air
Inner Tube
Air

Fig. 35. Burner, Engine 1450, S. P. Co.

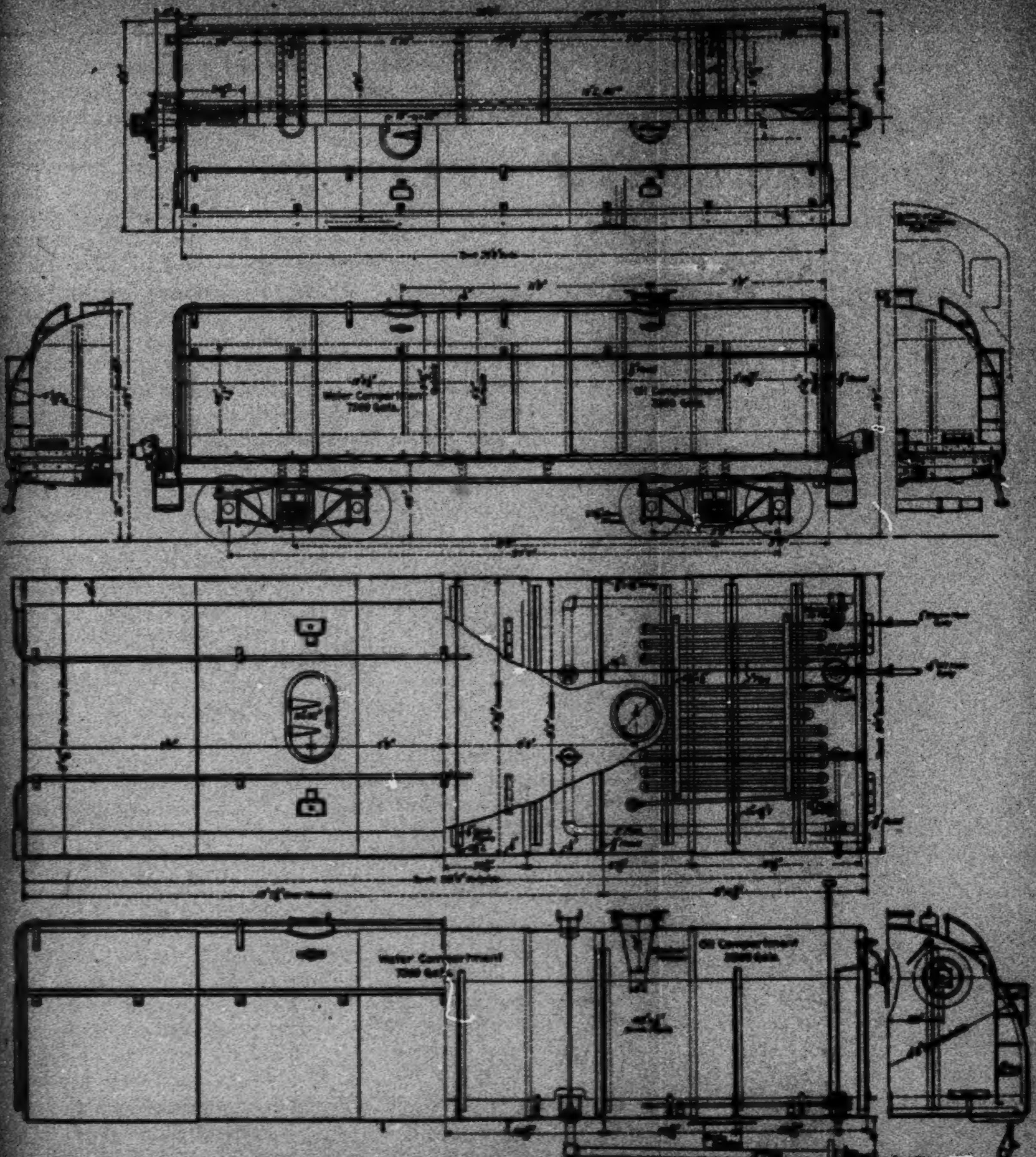

Water Compartment
Oil Compartment
Water Compartment
Oil Compartment

FIGURE 36
Semi-Cylindrical Tender and Tank for Oil Burning Locomotives—Southern Pacific.

"sideration natural draft, and add to it velocity of moving train, and "pump exhaust, all drawing cold air through the firebox, cooling sheets "and flues, and it will be seen that the consequences are sure to be "disastrous.

"Of course, burning oil in this country is in its infancy, and there is "room for a great deal of improvement, but considering the length of "time we have been at it, it is certainly remarkable to see how those "engines go up the hills with their heavy trains, with plenty of steam, "no smoke, no dust, no cinders, and no sweating fireman."

Combination Tenders.—Through the courtesy of the Southern Pacific Railroad Company, it is possible to present here a drawing of a semi-cylindrical tender and tank for oil-burning engines, of which several have been constructed. (See Fig. 36.) The tank is divided into oil and water compartments, the former of 3300 gallons, the latter of 7300 gallons capacity. The length, outside, is 28′ 6″, width 9′ 4″, height 6′ 5″, these being measurements on the tank proper. The curvature of top is struck on radius of 4′ 8″, the lower part of the sides being straight. The tank is constructed of ¼″ steel (sheets used being 69¾″ wide), with lap seams, single riveted with ⅝″ rivets, pitched 2″. A running board of 3/16″ material, 10″ in width, is carried along each side, with hand holds of 1″ iron pipe.

Manhole ring and plate for oil compartment are of cast iron, with opening 16″ in diameter. The cover is slightly convex in form, and is held in place by three bolts having hand wheel heads for ease of removal. The opening is provided with a six-mesh strainer, 22″ deep, and tapering to 6″ at the bottom. The interior of the compartment is provided with lateral and intersecting splash plates, and with a steam coil of 1″ pipe on the bottom. A small coil of ¾″ pipe, in series with the larger coil, surrounds the oil outlet. (It should be noted that these tanks are built for the heavy oil of Kern County.) The outlet valve, which discharges into a 1¼″ pipe, is controlled by a vertical lift rod attached to a bell crank, the latter being connected with another bell crank on the outside of the front head. It is customary to connect the outside bell crank with some point in the cab by means of a string, so that in case of a break-in-two the jerk on the string, in conjunction with the spiral spring above the valve, will operate to close the latter. The vertical rod just beside the valve rod, and extending through the top of the tank, is a measuring stick.

The water compartment has the usual equipment of splash plates and outlet valves, the latter being surrounded by copper strainers, and discharging into 3″ pipes leading beneath the floor to the front of the tender.

Cost of Converting a Coal-Burning Engine.—Through the courtesy of the Santa Fé Railroad Company, a detailed statement is here given of the cost, for labor and material, incurred in changing a 20" by 26" ten-wheel engine from coal to oil burning, the figures being approximately correct for nearly all classes converted by that company, with the exception of the charge for fire-brick, which would naturally be less in a smaller engine.

Oil reservoir: drilling, tapping, placing, and securing	$21 60
Automatic valve	3 90
Heater in oil tank	5 20
Heater pipes	1 20
Reducing valve	4 54
Air pipes	6 30
Burner	3 10
Heater box	3 00
Heater hose	1 40
Oil hose	2 15
Stopcocks	1 53
Regulators	2 16
Atomizers and pipes	95
Brick walls and arch	42 25
Oil pipes	55
Erecting: blacksmith, machinist, and labor	32 50
Removing coal-burning appliances	3 00
Ashpan: material, building, and placing	14 75
Sandbox and funnel	2 50
Pop and air gauge	5 06
Oil tanks (two)	174 83
Total	$332 47

The first engine fitted for burning oil, on the Santa Fé Railroad, was Southern California No. 10, in the local freight service between Los Angeles, San Bernardino, and Barstow. The oil-burning apparatus was put in place early in December, 1894, and the performance card for that month shows as follows:

Total miles run	3,147
Fuel oil, cost per mile	21.68 cents.
Repair account, per mile	2.25 cents.
Miles run per ton of fuel oil	34.34
Total fuel oil used	91 tons 1290 lbs.
Cost of oil per ton	$7.44

During this time, engines burning coal on this run made about fifteen miles per ton of coal.

Locomotive performance statistics for the year ending June 30, 1902, for the Southern California Division of the Santa Fé Railroad are as follows:

Total miles run	1,948,522
Average miles run per engine	48,967
Fuel oil, cost per mile	17.34 cents.
Repair account, per mile	9.35 cents.
Miles run per ton of fuel oil	29.91
Total fuel oil used	65,157 tons.
Average cost of oil, per ton	$5.18

The great divergence in repair charges per mile is due to two reasons: first, that engine No. 10 was thoroughly overhauled before being oil-fitted, and all brickwork, arches, etc., were new; second, that the repair account for 1901–02 included the refitting of a number of old engines.

Locomotive Fuel Tests.—The following records of fuel tests on locomotives are due to courtesy of the Motive Power Department of the Santa Fé Railroad Company, Southern California Division:

A comparative test of Texas and California petroleums (see Table 11 below) was made under the conditions here noted:

Texas Petroleum—
Source—Beaumont, Texas.
Gravity—21.5° Beaumé.
Weight per gallon—7.644 pounds.
Viscosity—Thin, used cold.

California Petroleum—
Source—Olinda (Fullerton field), California.
Gravity—15.5° Beaumé.
Weight per gallon—7.710 pounds.
Viscosity—Thick, warmed before using.

Engine Used—
18" x 24" eight-wheel Manchester.

Running in—
Local passenger service, Los Angeles and San Bernardino.

Number of Trips—
Ten with each oil, over the same run, with the exception that on two trips, due to change in time-card, run was extended from Riverside to Casa Blanca, 4.1 miles. This accounts for the difference of 16 engine miles and 32 car miles on the two records.

Roundhouse Oil Consumption—
On account of the varying amount of oil used in the roundhouse on the different runs, due to varying lay-over, it was thought fair to divide the total amount used equally between the runs; this accounts for the uniform figure of 440 pounds.

Injector Waste Water—
The water wasted is the amount lost at the injector overflow. This was determined by attaching an automatic counter to the injector handle, thus recording the number of times of application, and averaging the waste per application from a number of trials collected and weighed, the average being 20 pounds overflow to each opening of the injector.

TABLE 11. COMPARATIVE LOCOMOTIVE TESTS OF TEXAS AND CALIFORNIA OILS BY SANTA FE RAILROAD.

	Kind of Oil	San Bernardino to Los Angeles via Loop and Pasadena	San Bernardino to Los Angeles via Riverside and Orange	Los Angeles to San Bernardino via Riverside and Orange	Los Angeles to San Bernardino via Pasadena and Loop	General Average for all Runs	Grand Total for all Runs
Pounds of oil used on road	Tex.	3,506	3,291	2,735	3,888		33,081
	Cal.	3,573	3,620	2,592	3,705		33,149
Pounds of oil used in roundhouse	Tex.	440	440	440	440		4,400
	Cal.	440	440	440	440		4,400
Pounds of oil used, total	Tex.	3,946	3,731	3,175	4,328		37,481
	Cal.	4,013	4,060	3,032	4,145		37,549
Pounds of oil used per ton mile, excluding amount used in roundhouse	Tex.	0.31728	0.29333	0.40144	0.34624	0.33529	
	Cal.	0.32342	0.29054	0.38656	0.35151	0.33588	
Pounds of oil used per ton mile, including amount used in roundhouse	Tex.	0.35706	0.33255	0.46606	0.38545	0.37968	
	Cal.	0.36331	0.33507	0.45201	0.39629	0.38046	
Pounds of oil used per car mile, excluding amount used in roundhouse	Tex.	9.6840	8.9429	11.5401	10.7601	10.1320	
	Cal.	9.7455	8.7927	10.9396	10.6465	9.9278	
Pounds of oil used per car mile, including amount used in roundhouse	Tex.	10.8585	10.1386	13.3966	11.9767	11.4796	
	Cal.	10.9478	9.8819	12.7918	11.9108	11.2456	
Engine miles per ton of oil, excluding amount used in roundhouse	Tex.	49.70	59.99	57.76	44.43	52.60	
	Cal.	48.80	59.05	60.98	47.09	53.45	
Engine miles per ton of oil, including amount used in roundhouse	Tex.	44.16	52.91	49.74	40.26	46.42	
	Cal.	43.44	52.65	52.12	42.05	47.19	
Water used, pounds	Tex.	38,324	37,484	30,162	44,016		368,461
	Cal.	40,430	43,098	28,957	43,608		381,574
Water wasted, pounds	Tex.	780	680	507	900		7,020
	Cal.	807	830	553	930		7,600
Water evaporated, pounds	Tex.	37,544	36,804	29,656	43,116		361,441
	Cal.	39,624	42,268	28,404	42,678		373,974
Pounds of water evaporated per pound of oil—actual	Tex.	10.707	11.168	10.842	11.090	10.926	
	Cal.	11.001	11.674	10.958	11.515	11.281	
Pounds of water evaporated from and at 212° F. per pound of oil	Tex.	12.869	13.393	13.005	13.261	13.090	
	Cal.	13.296	13.979	13.129	13.769	13.504	
Steam pressure (average), pounds	Tex.	159.8	159.2	159.8	159.0	159.4	
	Cal.	161.0	161.2	160.6	161.2	161.5	
Temperature of feed water (average), °F.	Tex.	66.2°	69.2°	68.5°	72.1°	69.0°	
	Cal.	70.2°	70.8°	71.0°	72.5°	71.1°	
Temperature of fuel oil (average), °F.	Tex.	69.8°	75.7°	68.3°	76.0°	72.4°	
	Cal.	80.4°	81.7°	82.5°	86.5°	82.8°	
Average speed in miles per hour, deductn'g for stops	Tex.	36.72	37.59	38.44	35.43	37.04	
	Cal.	36.05	36.17	36.22	35.79	36.06	
Engine mileage	Tex.	87.1	98.7	78.9	87.1		870
	Cal.	87.1	106.9	78.9	87.1		888
Car mileage	Tex.	385	369	237	361		[illegible]
	Cal.	388	413	237	348		[illegible]
Ton miles	Tex.	11,109	11,219	6,812	11,232		[illegible]
	Cal.	11,070	12,128	6,707	10,539		[illegible]

TABLE 12. COMPARATIVE LOCOMOTIVE TESTS OF VARIOUS COALS AND OILS BY SANTA FE RAILROAD.

Date.	Duration of Test, Hours	Burner	Kind of Fuel.	Water Used per Hour	Horsepower Developed	Evaporation per Pound of Fuel—Actual	Factor.	Evaporation from and at 212° F.	Front End Vacuum, inches	Front End Temperature	Moisture in the Steam, per cent.	Evaporation from and at 212°, corrected for moisture	Steam Used by Atomizer, per cent.	Evaporation Corrected for Atomizer, per cent	Stack Gas Analysis, per cents.		
															CO_2.	O.	H.
April 5	22	1	Beaumont Crude	6,386	213	11.70	1.205	14.09	2.50	--------	2.00	13.87	--------	--------	--------	--------	--------
April 6	33	2	Beaumont Crude	5,310	177	11.28	1.205	13.59	1.30	--------	2.00	13.38	2.86	12.99	--------	--------	--------
April 10	2⅓	3	Beaumont Crude	4,646	155	9.18	1.205	11.06	1.00	--------	2.00	10.89	--------	--------	--------	--------	--------
April 11	1	3	Corsicana Crude	8,390	279	11.33	1.200	13.59	3.00	1015°	2.00	13.38	3.57	12.90	11.2	3.00	--------
April 17	2	4	Beaumont Crude	8,620	258	11.67	1.203	14.03	2.60	800°	1.14	13.91	3.71	13.39	11.2	3.00	--------
April 23	1	5	Beaumont Crude	7,850	262	13.06	1.201	15.67	4.00	728°	1.06	15.55	3.37	15.02	8.0	7.39	--------
May 1	3	5	Corsicana Crude	5,145	171	11.86	1.201	14.24	1.75	--------	1.13	14.12	4.70	13.45	8.7–7.5	8.3–8.9	--------
May 8	3	1	Corsicana Crude	5,775	192	13.38	1.200	13.69	1.44	625°	1.10	13.56	7,08	13.62	9.5	5.50	3.10
May 18	1	2	Corsicana Crude	6,635	221	12.15	1.192	14.48	1.46	821°	0.90	14.37	2.78	13.97	7.2	8.90	--------
May 24	2⅓	5	Corsicana Crude	6,150	205	12.09	1.199	14.49	1.54	761°	0.80	14.40	2.84	13.99	--------	--------	--------
May 31	1	5	Corsicana Crude	10,125	338	11.70	1.198	14.01	4.59	--------	0.72	13.93	4.86	13.25	--------	--------	--------
July 17	1	7	Distillate 24°	7,560	251	12.31	1.188	14.63	3.62	715°	0.67	14.56	2.11	14.28	--------	--------	--------
July 24	1	8	Distillate 24°	5,350	177	12.89	1.188	15.31	1.28	612°	0.72	15.23	2.05	14.86	--------	--------	--------
March 16	2⅝	---	Missouri Coal	4,016	134	6.35	1.204	7.64	1.25	--------	0.64	7.61	Nozzle opening, $9\frac{1}{16}$″.				
March 18	8	---	Virginia Coal	5,160	172	8.16	1.209	9.86	2.62	--------	1.10	9.78	Nozzle bushed to $3\frac{1}{16}$″.				
March 20	6¼	---	Virginia Coal	5,762	192	6.04	1.210	7.74	6.05	--------	0.87	7.69	Nozzle bushed to $3\frac{13}{16}$″.				
March 20	2	---	Missouri Coal	4,987	165	4.72	1.208	5.70	6.60	--------	0.90	5.67	Nozzle plugged, $7\frac{7}{8}$″ holes.				

Comparative tests of various coals and oils have also been made by the Santa Fé Railroad, Table 12, on page 111, being from a series of tests made at Topeka, Kansas, during 1901. For a variety of reasons the burners used are here designated by number, it being desired to show at this point merely a comparison between the values of the stated varieties of coal and oil, in this service. It may be noted, however, that the difference between the performance of the various burners is not great enough to lead one to look for any great difference in their value, so far as efficiency is concerned; this corresponds with the general experience in stationary work.

The details as to conditions under which these tests were made are not included in the data at hand:

TABLE 13. EVAPORATIVE TESTS OF OIL ON LOCOMOTIVE, MADE BY SANTA FE RAILROAD AT SAN BERNARDINO, CAL., OCTOBER 14, 15, AND 16, 1902.

DATE, 1902.		Oct. 14.	Oct. 15.	Oct. 16.	Oct. 16.	Average.
Train number		Extra.	Extra.	Extra.	Extra.	
Weather conditions		Clear.	Clear.	Clear.	Clear.	
Time on road		2h 15m	2h 47m	4h 50m	4h 4m	3h 29m
Dead time		25m	13m	1h 54m	1h 13m	56m
Actual running time		1h 50m	2h 34m	2h 56m	2h 51m	2h 33m
Average running speed, miles per hr.		13.77	9.81	8.60	8.84	10.26
Number of cars in train	Loads	3	10	10	8	
	Empties	11	2	2	8	
Tonnage of train		318	†351	365	360	349
Temperature of oil, degrees Fahr.		115	126	147½	150	134⅝
Gravity of oil, degs. Beaumé at 60° F.		12.9	14.1	13.0	13.8	13.5
Average pounds boiler pressure		168	184	186	185	181
Total pounds of oil consumed		4,922	6,820	6,990	7,285	6,504
Total pounds of water evaporated*		53,740	69,135	78,679	75,508	69,266
Pounds of water evaporated per pound of oil		10.92	10.14	11.26	10.36	10.67
Total ton miles		8,014	8,443	9,198	9,072	8,682
Oil burned per 100 ton miles		61.42	80.78	75.99	80.30	74.62
Temperature of water, degrees Fahr.		72	70	66	65½	68⅜
REMARKS		Low steam; oil too cold to atomize well.	Engine smoked badly.	Engine smoked slightly.	Engine smoked slightly.	

*No deductions for water lost at overflow.

†23-ton car set out at Verdemont.

TABLE 14. EVAPORATIVE TEST OF OIL AS FUEL ON SAN PEDRO, LOS ANGELES & SALT LAKE RAILWAY.

On trips from San Pedro to Los Angeles, up a one-sixth of one per cent grade, with train of four passenger cars. Distance, 28 miles. Time, one hour. Engine, Brooks, ten wheels, 20" x 28" cylinders, piston valve; weight, 153½ tons.

Date, 1902.	No. of Train.	No. of Stops.	Gallons of Oil.	Gallons of Water.
July 25	2	20	160.18	2,146
July 26	2	20	136.86	2,069
August 5	2	19	137.50	1,916
August 6	2	20	137.18	2,300
August 6	6	18	137.50	1,830
August 7	2	18	138.86	1,916

Average number of barrels of oil per trip, 3.35. Evaporation at 60° F., 14.99.

Average number of gallons of water per trip, 2029.5. Evaporation from and at 212° F., 18.19.

Average number of gallons of oil per car, 35.17. Oil per car per mile, 1.25.

Oil, asphaltum base, of 15° gravity Beaumé, reckoned 100% pure, although containing about 5% moisture and foreign matter. Used gravity pressure only. Oil weighed 8 pounds per gallon; water, 8.33 pounds per gallon. No water blown out of boiler between measurements.

The Southern Pacific Railroad Company has lately adopted a system of setting which does away with combustion chamber. The burner is introduced through the *front* end of the ashpan, just below the mud ring. Air for combustion enters at the usual point, through the bottom of the ashpan near the rear end, and passes to the forward end under a floor of fire-brick laid on iron plates. On reaching the front of the pan it is turned back by a second floor of similar construction, placed just below the level of the burner, finally issuing into the firebox, at the rear end, at a high temperature, having been heated by contact with the hot brickwork of the channels. The flame from the burner strikes a heavy fire-brick wall at the rear end of the firebox, turning up and back into the tubes. As the burner is turned directly away from the tube-sheet, there is no possibility of the flame playing directly on tube ends, and the expensive and cumbersome arch is thus avoided.

CHAPTER 11.

LIQUID FUEL ON STEAMSHIPS.

The use of petroleum on steamships, while very important from the commercial standpoint, and of considerable interest, involves very little departure from the principles established for the use of oil in stationary work. Aside from the fact that compressed air is generally (though not exclusively) used in place of steam, for injecting the oil, and that either water-tube or internally-fired boilers are used almost without exception, the arrangement of tanks, pumps, piping, and burners is much the same as would be found in a power plant of the same general dimensions on land.

The commercial importance of the use of oil for marine power is shown by the fact that there are now running out of San Francisco one hundred and thirty-seven vessels using oil for fuel, the gross tonnage being 106,543. A list of these vessels, furnished through the courtesy of Messrs. Bolles and Bulger, United States Local Inspectors of Steam Vessels, follows:

TABLE 15. LIST OF OIL-USING VESSELS LICENSED AT THE PORT OF SAN FRANCISCO.[1]

Name.	Gross Tonnage.	Service.
Aberdeen	499	Coaster.
A. C. Freese	206	San Francisco Bay.
Acme	416	Coaster.
Ada Warren	45	....
A. H. Payson	158	San Francisco Bay.
Alameda	3158	S. F. to Honolulu.
Albion River	450	Coaster.
Alcatraz	255	Coaster.
Alice	400	Yukon River.
Alliance	679	Coaster.
Alton	106	San Francisco Bay.
Amador	985	S. F. Bay ferry.
Apache	938	Sacramento River.
Arctic	392	S. F. to Eureka.
Argyle	2953	Coaster.
Asuncion	2196	S. F. to Redondo.
Aurelia	440	S. F. to Portland.
Bee	300	Coaster.
Bella	370	Yukon River.
Berkeley	1945	Oakland ferry.
Brooklyn	674	Coaster.
Brunswick	450	Coaster.
Casadero	1500	Sausalito ferry.
Centralia	800	Coaster.
Chas. Counselman	128	Coaster.
Charles R. Spencer	474	Coaster.
Chehalis	663	Coaster.
Columbia	2721	S. F. to Portland.
Comet	50	Columbia River tug.
Coronado	396	Ferry, San Diego.
Coronado	578	Coaster.
Dauntless	269	Tug.
Del Norte	450	Coaster.
Despatch	695	Coaster.
Dollar	10	Launch.
Dover	244	San Francisco Bay.
Eagle	2	Launch.
El Capitan	1100	Oakland ferry.
Elkkader	31	At Portland.
Encinal	2014	Oakland ferry.
Enterprise	2675	Coaster.
Eureka	494	Coaster.
Eureka of Seattle	3015	Coaster.
F. A. Kilburn	450	Coaster.
Falcon	117	Coaster.
Flora	185	Coaster.
Florence	90	Yukon River.
Fort Bragg	317	Sacramento River.
Frances Leggett	2800	Coaster.
Fulton	296	Coaster.
Garden City	1080	Oakland ferry.
G. C. Lindauer	429	S. F. to Gray's Harbor
General Frisbie	544	S. F. to Vallejo.
Geo. Loomis	601	Oil-tank coaster.
Geo. W. Elder	1709	S. F. to Portland.
Hannah	1211	At Portland.
Hazel	80	Puget Sound.
Hercules	96	San Francisco Bay.
Herman	819	Yukon River.
Hermosa	454	Coaster.
H. E. Wright	562	S. F. to Stockton.
H. J. Corcoran	682	S. F. to Stockton.
Iaqua	712	Coaster.
Imp	10	Launch.
Iralda	90	At Portland.
Jacinto	235	San Francisco Bay.
J. D. Peters	864	S. F. to Stockton.
J. S. Higgins	450	Coaster.
Kehani	118	Columbia River.
Leader	400	S. F. to Stockton.
Leah	477	Alaska.
Leon	692	Yukon River.
Linda	692	Yukon River.
Louisa	717	....
Luella	412	Coaster.
Mariposa	3158	S. F. to Tahiti.
Marshfield	398	Coaster.
Mary Garratt	610	S. F. to Stockton.
Monticello	226	S. F. to Vallejo.
Modoc	929	S. F. to Sacramento.
Napa City	178	S. F. to Napa.
Nebraskan	4409	S. F. to New York.
Nevadan	4408	S. F. to Honolulu.
Newark	1783	Oakland ferry.
No Wonder	209	Columbia River.
Oakland	1672	Oakland ferry.
Ocean Wave	724	Pt. Richmond ferry.
Olympic	450	Coaster.
Pasadena	300	Coaster.
Piedmont	1854	Oakland ferry.
Pilot	126	....
Pomo	268	S. F. to Point Arena.

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[1] Corrected to March 20, 1904.

TABLE 15. LIST OF OIL-USING VESSELS—Continued.

Name.	Gross Tonnage.	Service.
Prentiss	450	S. F. to Tillamook Bay.
President	564	S. F. to Alaska.
Priscilla	51	San Francisco Bay.
Red Bluff	246	San Francisco Bay.
Redondo	679	Coaster.
Rescue	172	Tug.
Richmond	135	Tug.
Rosecrans	2700	Coaster.
Sadie	276	At Seattle.
Salvador	800	....
Samoa	377	Coaster.
San Gabriel	484	Coaster.
San Joaquin No. 2.	242	Sacramento River.
San Joaquin No. 3.	220	Sacramento River.
San Joaquin No. 4.	365	Sacramento River.
San Jose	1115	Berkeley ferry.
San Pablo	1684	Pt. Richmond ferry.
Santa Monica	497	Coaster.
Sarah	1211	Yukon River.
Sausalito	1766	Sausalito ferry.
Sea Fox	69	Tug.
Sea King	181	Tug.
Sea Prince	56	Tug.
Sea Queen	111	Tug.
Searchlight	100	....
Sea River	80	Tug.
Shasta	722	Coaster.
Solano	3549	Port Costa fr'ght ferry.
South Bay	600	Coaster.
St. Helena	205	S. F. to Napa.
St. Vallier	60	San Joaquin River.
Susie	1211	Yukon River.
Tamalpais	1584	Sausalito ferry.
T. C. Walker	786	S. F. to Stockton.
Thoroughfare	1012	Oakland freight ferry.
Tiger	200	Tug.
T. J. Potter	1017	....
Transit	1506	Oakland freight ferry.
Union	67	Tug.
Valletta	419	S. F. to Sacramento.
Varina	150	San Francisco Bay.
Vulcan	227	Coaster.
Warrior	122	Coaster.
Wizard	129	Coaster.
Yerba Buena	1115	Berkeley ferry.
137 vessels	106,543	gross tons.

Where small vessels ply on the bay, or to nearby coast ports, fuel supply is always available at close range, and the minimum tank capacity often need not be more than will hold a few hours' run; but where oil-using vessels ply to distant ports at which oil is not to be had, provision for the return trip must be made in calculating the necessary tankage. Fuel oil is now kept in store at Los Angeles, Port Harford, San Francisco, and Portland, on the Pacific Coast, at points in the Hawaiian Islands, and at some Asiatic ports.

Storage Space.—If a vessel was intended to run between San Francisco and some port where oil for the return trip could be had, the storage space would be about 56% of that required for coal. For every hundred tons of coal required on the trip, four hundred barrels of oil would be needed, if we take the usual estimate of four barrels to the ton of coal; this figure probably holds good, on the average, on sea as well as on land. Four hundred barrels of oil occupy a space of 2246 cubic feet, net. One hundred tons of average steam coal would occupy a space of about 4000 cubic feet, making the space required for the oil 56% of that taken by the coal. But if the vessel ran to a port where coal fuel for the return trip was available, while oil was not to be had, the space required for the oil would be just double the above amount, or 12% in excess of the coal space necessary. This comparison overlooks, however, one fact of considerable practical importance: that coal must, for obvious reasons, be stored close to the boiler, while oil, being readily pumped from any point desired, may often be stored in space not otherwise useful.

Fuel Weight.—If a vessel plies to a port where oil for return fuel is available, the weight of oil carried is about 60% of that of the equivalent coal. For every hundred tons (224,000 pounds) of coal consumed on the trip, four hundred barrels of oil would be required, weighing, at 15° gravity, 337 pounds per barrel, or 134,800 pounds. As the fuel is, generally at least, used in equal amounts every hour of the trip, both solid and liquid fuel carried would diminish in weight from the gross amount at the start to zero at the end of the trip, and the average weight carried would of course be half the initial weight, or 112,000 pounds for coal, and 67,400 pounds for oil, making the weight of oil 60.2% of weight of coal.

But if a vessel is on a run where oil is available at one end only, while coal may be had at both ends, the weight of oil carried is much in excess of that of coal. Taking the same hundred tons of coal to represent the amount used on the run, the coal carried would be the half of one hundred tons to each run, or one hundred tons (224,000 pounds) to the round trip. Oil would have to be carried on the out trip for the return, so that the vessel would carry on the out trip 202,200 pounds, and on the return 67,400 pounds, a total of 269,600 pounds, or an excess of 20.4% over the average weight of coal.

As would be expected from experience on land, the use of oil at sea is the means of increasing the speed capacity, and of extending the sailing radius. It materially reduces the fire-room force, as the coal-passer is eliminated, and one fireman can, on a large vessel burning oil, do the work of four where coal is used. It reduces the labor in port, on cleaning both outside and inside of boiler-room. The claim was once made that the use of oil shortened the life of the boiler, but this belief seems to be amply disproven by longer experience. In tropical climates it is a material factor that the fire-room temperature is considerably reduced, where oil is used, and the very hard labor of shoveling coal and slicing fires at high temperatures done away with. The oil fire, also, for reasons already pointed out, contains in itself the elements of moderate forced draft, and obviates the necessity of air pressure on the fire-room, up to a certain point, say that at which one inch of water pressure would be carried with coal.

In spite of the wide extent to which oil has been and is being used on vessels sailing from San Francisco and other Pacific Coast ports, but little definite data are available as to relative economies. The economic advantage in using oil for fuel, at present prices, is so manifest that those who have looked into the matter have usually adopted oil without much experiment, while those by whom it is used are usually satisfied to find their fuel bills decreased fifty per cent or more, without caring to inquire into the details.

Government Boiler Tests.—The most, one might almost say the only, comprehensive tests which have been made with liquid fuel in direct comparison with coal were undertaken in 1902 by the Bureau of Steam Engineering of the United States Navy. These tests are still under way, but a report has been issued describing the results obtained from the first trials, thirty-one in number.[1] The tests were made with the Hohenstein water-tube boiler, in a special experimental plant so constructed as to imitate, on land, the conditions met in the fire-room of a war vessel. For the details of these tests, which will amply repay the closest examination, reference must be had to the original report, as the figures are far too voluminous to reproduce in full. But the main points brought out in the course of the trials may be gathered from the following tables, summarized from the various tables in the report.

The coals used were Pocahontas and New River, rated among the best of American bituminous coals, and having the following analyses:

	Pocahontas Coal, Run of Mine.	Pocahontas Coal, Run of Mine.	New River Coal, Run of Mine.	Pocahontas Coal, Hand Picked and Screened.
Proximate Analysis.				
Fixed carbon	73.30%	75.78%	72.99%	76.81%
Volatile matter	17.61	19.53	21.79	19.62
Moisture	0.49	0.79	0.49	0.73
Ash	8.60	3.90	4.73	2.84
	100.00	100.00	100.00	100.00
Sulphur, separately determined	0.48	0.71	0.46	0.82
Ultimate Analysis.				
Carbon	82.26%	84.96%	83.60%	85.94%
Hydrogen	3.89	4.07	4.85	4.45
Oxygen	4.12	5.46	4.87	4.50
Nitrogen	0.64	0.90	1.41	1.14
Sulphur	0.49	0.71	0.46	0.82
Ash	8.60	3.90	4.81	3.15
	100.00	100.00	100.00	100.00
Calorific Value (B. T. U.) per Pound.				
Coal	14,067	14,594	14,841	14,982
Combustible	15,391	15,124	15,084	15,475

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[1] "Report of the 'Hohenstein Boiler' and 'Liquid Fuel' Boards," of the Engineering Department, U. S. Navy, 1902.

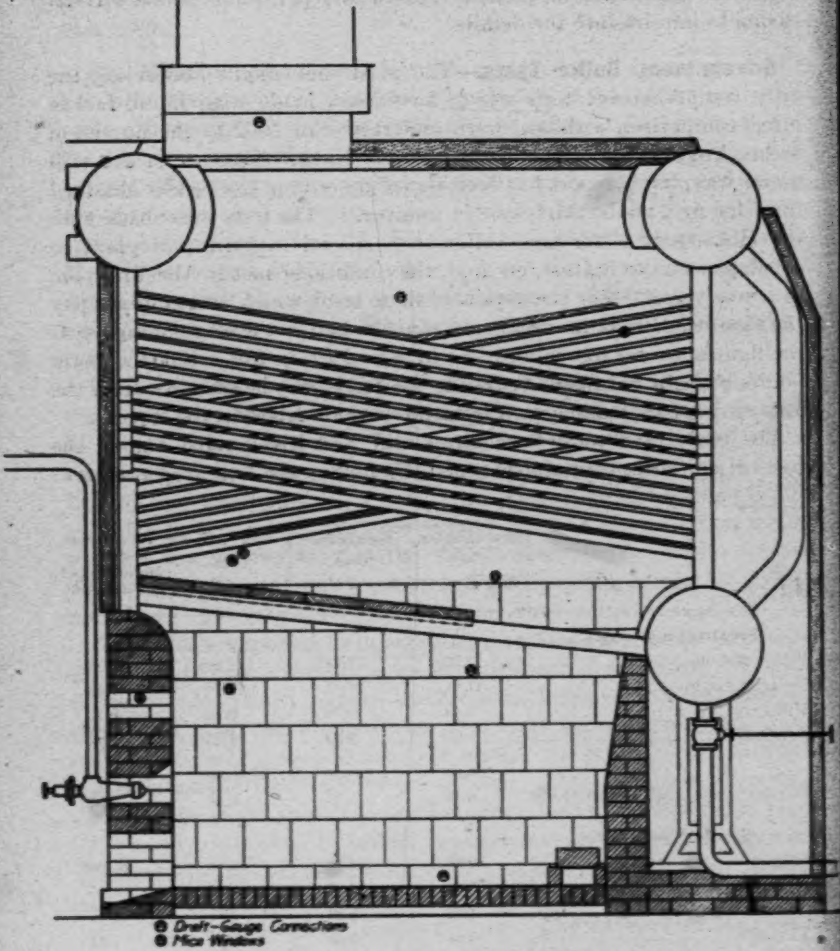

Fig. 30. Hohenstein Experimental Boiler, arranged for Oil.

(Reproduced from Report of the Liquid Fuel Board, U. S. N.)

The oil used was a reduced oil from Beaumont, Texas, having the following analysis:

Proximate Analysis.

First ten per cent passed over	Between 212° and 482° F.
Second ten per cent passed over	Between 482° and 523° F.
Third ten per cent passed over	Between 523° and 582° F.
Fourth ten per cent passed over	Between 582° and 680° F.

Distillation at atmospheric pressure.

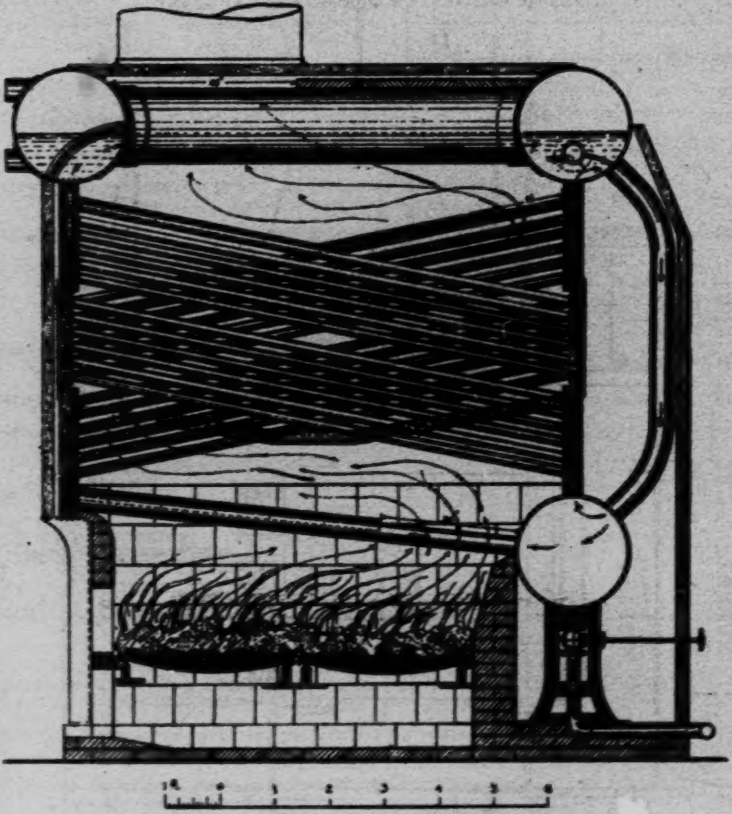

FIG. 40. Hohenstein Experimental Boiler, arranged for Coal.

(Reproduced from Report of the Liquid Fuel Board, U. S. N.)

Ultimate Analysis.

Carbon	83.26%
Hydrogen	12.41%
Sulphur	0.50%
Oxygen	3.83%
	100.00%

Physical Properties.

Specific gravity at 60° F.	0.926
(Equal to degrees Beaumé)	21.2°
Flash point	216° F.
Fire point	240° F.
Vaporization point	142° F.
Loss for six hours at 212° F.	21.05%
Calorific value, calculated from Dulong's formula	19,461 B. T. U.

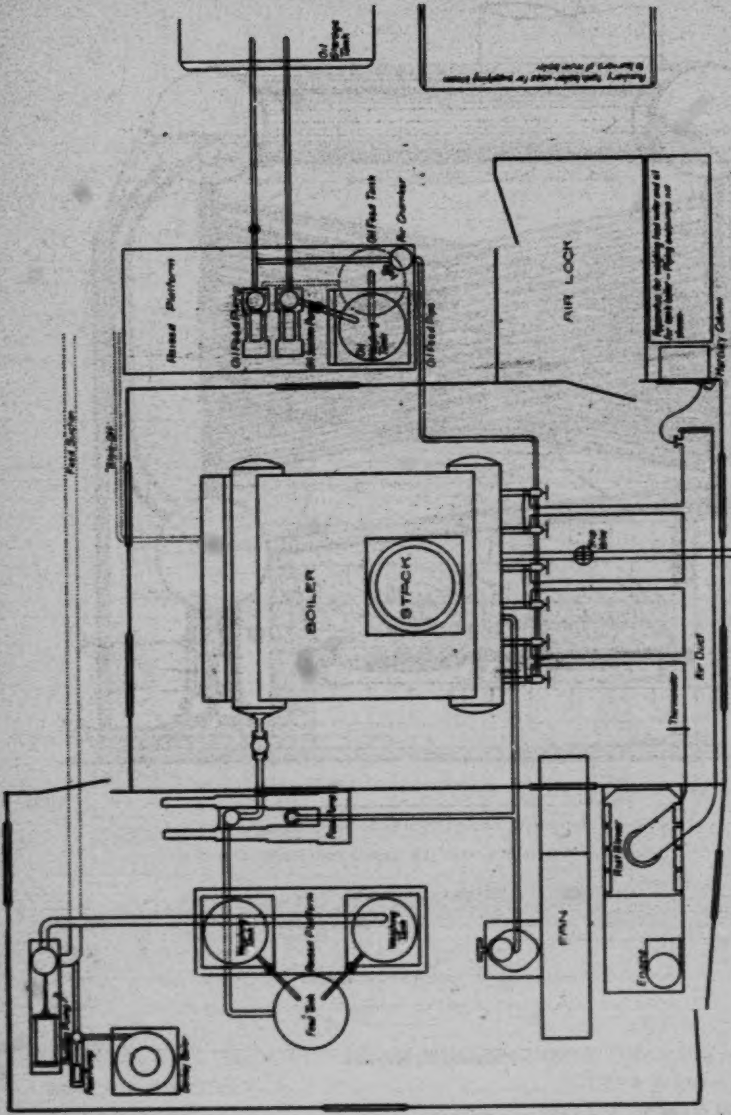
BOILER
STACK
AIR LOCK
FAN
Air Duct
Raised Platform
Oil Feed Pump
Oil Feed Tank
Air Chamber
Oil Feed Pipe
Oil Storage Tank
Muffler
Thermometer
Engine
Feed Tank
Raised Platform
Humidity Column

Fig. 41. Experimental Boiler Plant used in U. S. Navy Department Tests.

Fig. 39 herewith shows general arrangement of boiler and setting for use with oil; Fig. 40, the same as used with coal; and Fig. 41, the arrangement of boiler-room and connections during oil tests.

TABLE 16. HOHENSTEIN WATER-TUBE BOILER.

	Coal Tests.	Oil Tests.
Fuel used, total *lbs.*	106,778	190,770
Calorific value, average *B. T. U.*	12,965	19,481
Theoretical evaporative power per pound of fuel, from and at 212° F. *lbs.*	13.42	20.17
Water evaporated from and at 212° F., total *lbs.*	1,528,260	2,714,420
Evaporation per pound of fuel as fired, gross—		
Maximum *lbs.*	10.20	14.43
Minimum *lbs.*	8.22	10.77
Average *lbs.*	9.16	13.50
Steam used in injecting, or in compressing air for injection, average %	0.00	3.02
Net available evaporation per pound of fuel, average *lbs.*	9.16	13.18
Pounds of steam used in spraying oil, per pound of oil, using steam only—		
Maximum *lbs.*	....	0.701
Minimum *lbs.*	....	0.464
Average *lbs.*	....	0.568
Efficiency: percentage of theoretical heating value realized in actual evaporation, net—		
Natural-draft trials—Maximum %	68.3	70.7
Minimum %	60.0	60.9
Average %	64.4	65.6
Forced-draft trials—Maximum %	65.6	61.8
Minimum %	54.0	51.1
Average %	59.5	56.7
Number of trials using forced draft	11	4
Number of trials using natural draft	6	10
Average fire-room pressure during forced-draft trials, in inches of water	1.5	2.4
Evaporation per hour per square foot of heating surface, net—		
Natural-draft trials—Maximum *lbs.*	5.40	9.45
Minimum *lbs.*	4.38	3.91
Average *lbs.*	4.82	6.36
Forced-draft trials—Maximum *lbs.*	14.15	16.70
Minimum *lbs.*	6.28	10.50
Average *lbs.*	9.61	14.00

Fuels Used.—The coal used in these tests was of a much higher grade than any of the Pacific Coast coals, which will not average more than 10,500 to 11,000 B. T. U. per pound as fired. This makes the figures for evaporation with coal higher than they would be with local coals, both because of the higher evaporative power directly, and also because, in general, the better the coal used the higher will be the percentage of efficiency. On the other hand, the Beaumont oil used in the oil tests could hardly have been of better quality than the average California crude, and there is no reason to suppose that any higher rate of evaporation was secured than would have been had, under the same conditions, with local oil. The evaporation obtained with oil is, in fact, notably lower than has been had in California, in very carefully conducted tests, and under the same conditions, so far as efficiency of apparatus is concerned.

Steam in Burners.—Only a few of the trials used steam alone in the burners, some using air alone, others both air and steam. In the trials which used steam alone, the burners were of very simple construction, in two tests being practically a pipe burner, in three tests of the type shown in Fig. 23. The steam used, ranging from 0.701 lb. to 0.464 lb. per pound of oil used, would equal, at the average evaporation for these tests of 13.5 pounds, 5.12% to 3.4% of the total evaporation, the average being 4.2%. The lower percentage shown in the table above, in the line "Steam used in injecting," is due to this average covering also the tests using air in the burners, it being well known that air burners use less steam in the compressor than steam burners consume direct. As this average of 4.2% is somewhat larger than is customarily estimated in Pacific Coast practice, either the tests were wasteful of steam, or else the prevailing figures on the coast are wrong; probably the latter, as the greatest precautions were taken by the board to secure an accurate account of the steam used by burners, which were handled by skilled firemen and were of approved form.

Efficiency.—The efficiency during natural draft trials is notably low, being only slightly greater than realized with coal. A great number of tests made in California, by careful engineers, gave given efficiencies with oil fuel of 75% to 80%, with evaporation of 4½ pounds per hour per square foot, or better, under ordinary conditions of service. The efficiencies obtained with coal in these tests being good, it is probable that the low efficiency figures in the oil tests are due to over-estimation of the calorific value of the oil, this being calculated from the ultimate analysis by Dulong's formula. A number of comparative determinations made on California oil would indicate that the calorific value calculated from analysis in this manner is higher than the value found by combustion, and it is possible that the theoretical evaporative power stated for the Beaumont oil used is too high by 5%; if this is the fact the efficiencies as stated would average about 3% too low, though even if corrected by this amount they would still be considered low in California.

As would be expected, the efficiencies found on forced draft trials are somewhat lower than in the coal tests. It does not appear that oil is very suitable to use under forced draft conditions, though it may be that further experiment as to firebox and baffling arrangements will make it more adaptable. The board found in the tests above that they could not evaporate more than thirteen pounds of water per hour per square foot of heating surface, without forming a great deal of smoke and greatly lowering the efficiencies. As to this, much would depend on the form of the firebox, and probably also on the atomizing efficiency of the burners.

Capacity.—The evaporation per hour per square foot of heating surface (*i. e.*, the capacity) is considerably higher on the oil trials than when using coal. This agrees with the results of numerous trials in this State, which show that a good water-tube boiler using oil fuel can be forced, under natural draft, from 60% to 75% above rated capacity, without lowering the efficiency below 75%.

Conclusions of the Board.—The general conclusions drawn by the Engineers of the Board from the data collected are summed up as follows: "It is believed that expert engineers will be able to make "important deductions from the trustworthy data that have been so "carefully collected. The table should be carefully studied in connec- "tion with the information secured during the coal tests, and the board "enjoins that the two reports be studied together.

"The following information has undoubtedly been secured:

"(*a*) That oil can be burned in a very uniform manner.

"(*b*) That the evaporative efficiency of nearly every kind of oil per "pound of combustible is probably the same. While the crude oil may "be rich in hydrocarbons, it also contains sulphur, so that, after refin- "ing, the distilled oil has probably the same calorific value as the crude "product.

"(*c*) That a marine steam generator can be forced to even as high a "degree with oil as with coal.

"(*d*) That up to the present time no ill effects have been shown upon "the boiler.

"(*e*) That the firemen are disposed to favor oil, and therefore no "impediment will be met in this respect.

"(*f*) That the air requisite for combustion should be heated if possi- "ble before entering the furnace. Such action undoubtedly assists the "gasification of the oil product.

"(*g*) That the oil should be heated so that it could be atomized more "readily.

"(*h*) That when using steam higher pressures are undoubtedly more "advantageous than lower pressures for atomizing the oil.

"(*i*) That under heavy forced draft conditions, and particularly "when steam is used, the board has not yet found it possible to prevent "smoke from issuing from the stack, although all connected with the "tests made special efforts to secure complete combustion. Particularly "for naval purposes it is desirable that the smoke nuisance be eradi- "cated in order that the presence of a warship might not be detected "from this cause. As there has been a tendency of late years to force "the boilers of industrial plants, the inability to prevent the smoke "nuisance under forced draft conditions may have an important influ-"ence upon the increased use of liquid fuel.

"(*j*) That the consumption of liquid fuel can not probably be forced "to as great an extent with steam as the atomizing agent as when com-"pressed air is used for this purpose. This is probably due to the fact "that the air used for atomizing purposes, after entering the furnace, "supplies oxygen for the combustible, while in the case of steam the "rarified vapor simply displaces air that is needed to complete combus-"tion.

"(*k*) That the efficiency of oil-fuel plants will be greatly dependent "on the general character of the installation of auxiliaries and fittings, "and therefore the work should only be entrusted to those who have "given careful study to the matter, and who have had extended expe-"rience in burning the crude product. The form of the burner will "play a very small part in increasing the use of crude petroleum. The "method and character of the installation will count for much, but where "burners are simple in design and are constructed in accordance with "scientific principles there will be very little difference in their effi-"ciency. Consumers should principally look out that they do not "purchase appliances that have been untried and have been designed "by persons who have had but limited experience in operating oil "devices."

Steamer "Mariposa."—One of the first deep-sea vessels on the Pacific Coast to be fitted for oil was the Oceanic Steamship Company's "Mariposa," running from San Francisco to Tahiti. Through the courtesy of the Steamship Company, the Navy Department was permitted to send out a representative on the "Mariposa" on her first trip after being fitted with oil-burning apparatus. The following[1] is a description of the steamer "Mariposa," of the Oceanic Steamship Company, as fitted for oil fuel burning, with an account of the preliminary trial trips of the vessel as witnessed by Commander H. N. Stevenson, United States Navy; also the report of Lieut. Ward P. Winchell, U. S. Navy, who officially represented the Department on the round trip of the steamer between San Francisco and Tahiti:

The "Mariposa" is a single-screw iron steamer, built at the yard of William Cramp & Sons, Philadelphia, Pa., in 1883. She has just had new engines and boilers installed by the Risdon Iron Works, San Francisco, Cal. The oil-burning plant has just been installed by the same company. (July, 1902.)

This vessel has been employed in the Pacific trade, and is now running to Tahiti from San Francisco, making the round-trip voyage of 7320 knots each month.

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[1] Quoted from "Report of the Liquid Fuel Board."

Description of the "Mariposa."

Gross tonnage	3160	
Length between perpendiculars	314	feet
Beam	41	feet
Mean draft	22	feet
Depth of hold	$17\frac{4}{12}$	feet

There is a single bottom with four water-tight athwartship bulkheads, and two masts, square rigged on the foremast.

The total crew was 81, but since the change from coal to oil burning 16 men have been taken out of the engineer's force, reducing the crew to 65 men, and making the engineer's force for oil burning 20 men, as follows: 1 chief engineer, 3 assistant engineers, 3 oilers, 1 electrician, 1 attendant for ice machine, 1 attendant for air-compressor, 3 water-tenders, 6 firemen, 1 storekeeper.

The Engines and Boilers.—There is one triple-expansion engine of the inverted direct-acting type, with cylinders 29", 47", and 78", by 51" stroke, designed for 2500 indicated horsepower, fitted with piston valves on the high-pressure and intermediate-pressure, and slide valve on the low-pressure cylinders, all drawn by link motion. The condenser is part of the back framing. The cylinders are not jacketed.

The air, feed, and bilge pumps, of which there are two sets, are driven from the forward and after cross-heads. The centrifugal circulating pump is driven by a separate engine. The four-bladed propeller is 16' 6" diameter, and has a pitch of 23'.

There are three cylindrical tank boilers, placed fore and aft in the line of the ship—two are double-ended, 15' 3" diameter by 15' 3" long, and one single-ended, 14' diameter by 9' 9" long, the latter placed amidships, forward of and worked from the forward fire-room. Each double-ended boiler has six corrugated furnaces; the double-ended boilers have a common combustion chamber for opposite furnaces, while the single-ended one has a common combustion chamber for its three furnaces. There is one smokestack for all the boilers. The combustion chambers of the double-ended boilers have a brick wall, and the back sheet of the single-ended one is covered with fire-brick. The decision to use oil in place of coal was not made until the changes in engines and boilers were well under way, and it was decided to put the ship on the route to Tahiti. The steam pressure is 180 pounds. There is one auxiliary boiler, two-furnace return tube type, in upper fire-room hatch, and fitted to burn coal only.

The Oil Tanks.—These were constructed out of the old coal-bunker space, forward of the boilers, and as the steamer is intended to carry oil for the round trip of about 7320 miles, some additional space had to be taken from the fore-hold. They are arranged as follows: Just forward of the boiler space a solid water-tight bulkhead, well braced, was built from the berth deck to the single bottom of the ship, extending to the single skin of the ship, from side to side; four feet, or two frame spaces, forward of this, was also built another similar solid bulkhead, which formed the after ends of the oil tanks; forty-eight feet farther forward another similar solid bulkhead was built to form the forward heads of the oil tanks, and four feet forward of this another solid bulkhead. The spaces of four feet at each end of the tanks being a cofferdam space to catch any oil from leakage or accident, these cofferdam spaces can be filled with water if necessary. The tank space is divided into six tanks by a middle bulkhead and two side partitions. Splash plates to break the impact of rolling are placed in each tank, a small opening at the top allowing any accumulation of gas to pass off to the ventilating trunk. Small openings at the bottom allow free communication for the oil. Along the top of the tanks is provided an expansion head or trunk, being 4½' high and 4½' wide. Over each a ventilating trunk connecting with the top of each tank extends up to about five feet above the hurricane deck. The cofferdam spaces are ventilated by tubes reaching to the upper deck, fitted with cowls, one tube reaching to near the bottom to carry out any heavy gas that might accumulate there. From the upper deck the sounding pipes to each tank are reached. There are no pipes in or through the tanks except those connected with the oil service. The total capacity of the tanks, exclusive of expansion trunk, is 6338 barrels of oil—about 905.43 tons. One barrel of oil equals 42 gallons.

To fill the tanks, on the port side outside the ship a 6" connection is fitted; from this a pipe leads to the forward fire-room, where the tank oil pump is placed. This pump, horizontal duplex, steam cylinders 9", oil cylinders 8½", stroke 10", can be used to draw its supply from the pipe and deliver into each of the tanks, or by using by-passes, which are provided, the oil barge alongside can fill all the tanks; an overflow pipe from each tank, carried at height of deck above them, leads to an overflow outside the ship near the supply hose coupling.

There are two service or settling tanks, placed in pockets formed on either side of the single-ended boiler. They are reached by doors from the forward fire-room; each of these tanks holds about twelve hours' supply. They are filled by the oil tank pump, and have overflows back to the main tanks; ventilating tubes lead from near the bottom of the pockets in which they are placed to the smokestack.

Each service tank is provided with glass gauges, by means of which the amount used every hour or watch can be easily measured.

Each settling tank has two suction pipes, one at bottom to draw off water if necessary, the other at a height of about two feet for the oil supply to the service pumps. All the tanks are provided with manholes to reach the interior.

The Oil Service Pumps.—The oil service pumps, of which there are two, horizontal duplex, steam cylinders 6", oil cylinders 4", and stroke of 6", one being large enough to supply all the burners, are placed in the forward fire-room on either side. They draw their supply from the settling or receiving tank through removable strainers, placed so that they can be easily changed for cleaning, and discharge into the bottom of the small heating tank near them, where the oil is heated by a steam coil to not more than 150° F., and thence by a pipe to the burners. The air from the compressors, under a pressure limited to 40 pounds, discharges into the top of the heater tank on its way to the burners, so that the oil and the air go to the burners under the same pressure. The heater tank is provided with glass gauges, also a float to work a telltale and automatic control of oil supply pump.

The Air-Compressor.—The air-compressor is placed in a pocket off the upper engine-room platform, and consists of duplicate steam and air cylinders, connected to a crank shaft carrying a flywheel turning between the cylinders. Either set is large enough to supply all the air necessary. The air-compressor is horizontal, double acting, duplex. Air cylinders 22", steam cylinders 12", diameter, by 18" stroke for all cylinders. Capacity equals 1000 cubic feet of free air per minute, compressed up to 30 pounds, and 120 revolutions per minute. Air is used at the heat of compression, or as heated by the air heater.

The Atomizer.—The atomizer, for which patents are pending, is the joint invention of Messrs. Grundell and Tucker, San Francisco.

The atomizer consists of a hollow plunger for the oil, screwed into a pipe through which the air passes. The outlet for the oil is through a series of small holes, at right angles to the central hole. The air meets the oil through spiral directors and is sprayed into a rose shape by the expanded end of the atomizer.

The air and oil pipes have globe valves to regulate the supply of either, also plug cocks connected together to a handle, by means of which each burner can be shut off immediately in case of necessity, a slow-down bell, or other cause. The air-supply pipe is also connected with the steam line, so that steam can be quickly substituted for air if desired.

The length of the oil plunger is adjustable, to give the best form to the rose-shaped flame. Two burners are fitted to each furnace.

The Air Heater.—A part of each furnace front is a hollow iron casting, through which the air passes on its way to the atomizers and becomes heated. The chamber surrounding the burner is lined with a crucible lead lining; a by-pass to the burners is provided for use in case of accident to the heater. The lower part of the furnace front is a door on hinges that can be fastened open at any desired degree to give air for combustion. There are also two louvres in the door for the same purpose. Near the front of the furnace inside the door is placed a brick wall made to deflect upward the inward current of air to meet the rose-shaped flame from the burners. There is ample space over the brick wall for a man to enter the furnace through the ashpit door. The double furnace combustion chambers have a brick bridge wall reaching above the top of the furnaces, and in the single-ended boiler the common combustion chamber has the back sheet covered with fire-brick to protect it.

The Trial Trips.—Two trial trips with the vessel under way were made on July 5 and 11, the vessel being under way about eight hours each day, running from the vessel's dock to the Farallon Islands and return, and were made for the purpose of ascertaining if the oil apparatus, the new engines and boilers, were in good working condition. On the first run the boilers primed badly, owing to the construction dirt not having been thoroughly cleaned out. Before the second run they were cleaned, and worked well on this run.

The strainers on the oil-supply pipes were not finished and considerable trouble was found with dirty oil which clogged the burners. Neither the telltale to show the height of oil in the heated tank, nor the controlling device for the oil service pump were fitted, not being finished in time for use. No attempt was made to measure the amount of oil burned, nor to attain the maximum speed, and it was therefore impossible to obtain any data other than observation of the working of the oil apparatus.

Very few of the fire-room force had ever had any experience with oil burners on steamers, and one object of the trials was to give the force practical experience. When properly regulated the burners gave no smoke, but that they were not properly regulated is shown by the fact that more or less smoke was visible most of the time, and at times dense black. Owing to lack of the telltale and regulating device of the small heating tank the pump-tender once allowed this tank to fill up and the oil to flow over into the air pipe and flood the burners. As soon as this was discovered every burner was immediately cut off by means of the lever connecting to the plug cocks on the oil and air supply pipes at the burners.

The atomizer tubes were unscrewed and on some of them, where the oil had caked, considerable force had to be applied to pull them out. New, clean atomizers were screwed in, and as soon as the oil heater tank could be brought to the proper oil level the burners were started again. Some steam pressure was lost during this delay, but the engines did not stop nor slow down very much; some of the burners were started in a few minutes and all of them in not over fifteen minutes. The value of being able to shut off the air quickly and clean or substitute other atomizers was shown by this mishap. The burners made considerable roaring noise, and the air pressure was, in order to clean the burners of dirt, carried to about the intended pressure, owing to the lack of strainers which allowed dirty oil to choke them, and they had to be taken out frequently for cleaning. By shutting off with the lever the regulating valves were left in adjustment for starting again, provided it was right before. The new fire is started by a torch inserted into the plug hole around the burner.

On the second run the strainers and the regulating device for the heater tank had been completed. The oil apparatus was handled with greater ease and uniformity, and the less amount of smoke was very noticeable. For intervals of an hour or more scarcely any or none would be observed. On the run in from the Farallones the engine was speeded up to 74 to 77 turns, and an average speed of 14½ knots was obtained. The steam pressure was uniformly maintained at the point desired without difficulty, and the oil-burning apparatus gave no trouble whatever.

The oil used on both runs was from the Kern River district, near Bakersfield, Cal.

The following data were observed:

Steam pressure	160 to 170 lbs.
Revolutions of engine	74 to 77
Revolutions of air-compressor	60
Pressure of air	20 lbs.
Temperature of oil entering heater	30° F.
Temperature of oil leaving heater	120°-130° F.
Temperature at base of stack	750° F.

It is regretted that the nature of the trials did not permit of obtaining a greater amount of data beyond observing the apparatus in use.

The chemist of the New York yard submitted the following report upon the sample of the Kern River district oil sent him for analysis:

The sample is practically free from low-boiling naphtha, as on distillation only a small percentage passed over below 150° C., and less than 10% below 225° C. A boiling point above 360° C. was reached before the second 10% was collected.

It shows on ultimate analysis the following composition:

Carbon	84.43%
Hydrogen	10.99
Oxygen	3.34
Nitrogen	0.65
Sulphur	0.59

This gives a calorific value, by Dulong's formula, of 18,806 B. T. U. The specific gravity at 60° F. is 0.962 (15.5° Be.). Flash point, 228° F. Fire point, 258° F. Vaporization point, 178° F. Loss for six hours at 212° F., 12.01%.

REPORT OF LIEUT. WARD WINCHELL ON THE VOYAGE OF THE "MARIPOSA."

U. S. STEAMER "BOSTON,"
AT SEA, August 15, 1902.

SIR: In accordance with the Department's telegraphic order of July 7, 1902, delivered July 8, 1902, and the instructions from the Bureau of Steam Engineering, dated July 7, delivered a few minutes before sailing, I took passage on the Oceanic Steamship Company's steamer "Mariposa," leaving San Francisco at 10 A. M. July 15, 1902, for the round trip to Tahiti.

In accordance with the instructions of the Bureau, I took two sets of indicator cards each day, making forty-five sets in all, the data of which were worked up.

There have been no tests to determine the evaporative efficiency of the two main double-ended boilers used on the run, and I regret to report that the chief engineer of the ship was unable to improvise any apparatus by which the amount of feed water could be determined with accuracy enough to give the data any value.

The amount of oil is a matter of much importance, since the tanks hold barely enough to make the round trip and but one day's supply of coal is aboard. The oil was measured first by the amount pumped into the two settling tanks, as shown in inches on the scale back of the gauge glasses on the tanks; second, this amount was checked by the number of inches used out of each tank for each watch; third, another check, and the one considered most accurate, as dealing with large quantities and small errors, was by sounding the tanks from time to time and comparing the amounts taken out with the expenditures in the log. The latter method gave a correction which was applied to the daily log, increasing the daily expenditure slightly, as summed up by inches in the settling tank.

The most careful inspection at Tahiti failed to show any bad effect of the flame upon the boilers. No leaks nor defects developed anywhere about them and there was no difficulty at any time in feeding them. As I was ordered to the "Boston" immediately on my arrival at San Francisco I lost the opportunity of again inspecting the boilers, but no defects showed from the outside. At Tahiti the tubes were swept by tube-scrapers, and back connections, uptakes, ashpans, and furnaces were cleaned. All refuse from these various places barely filled two ash buckets.

This refuse, mainly soot, was the result not only of the twelve days' run to Tahiti, but also of the three preliminary trials by the contractors. The first one, a four-hour trial of engines and boilers, was made with Comax coal, and the other two were free runs at sea, of about eight hours' duration each, burning oil. The tubes had never been cleaned previous to arrival at Tahiti. It is the intention hereafter to make the round trip of twenty-four days' steaming without sweeping tubes.

There are no precautions other than those usually taken on board ship to guard against fire or explosion. All spaces to which oil has access are well ventilated by both inlet and outlet ducts. The oil is a thick, dark liquid, like molasses, and in the open air burns slowly, giving off much smoke. But it gives off volatile gases which form explosive mixtures with air, tanks empty or nearly so being more dangerous than full ones in this respect. The ship is electrically lighted, but in addition an open hand lamp is burning in the fire-room all the time to light the burners; the firemen smoke on watch, and the oil is treated no more tenderly than if it were coal. On the run back, the cargo of copra was stored all about the expansion trunk, which projects up 4½ feet between decks, completely covering the tanks and making them inaccessible for examination.

Of the six firemen, three were relieved from watch the second day out, leaving but one man on a watch to fire twelve furnaces in two different fire-rooms separated by the length of the double-ended boilers. The water-tender did not touch the burners except in emergency, his duty being to 'tend water, fill settling tanks and record height of oil in them, record temperatures of oil at settling tank and in heater, of fire-room and of superheated air, take reading of lower pyrometer where the two uptakes meet, and run oil pump supplying oil to the settling tanks and small oil pump supplying oil to the oil heater.

As a coal burner the "Mariposa" formerly had the following engineer force: 1 chief engineer, 3 assistant engineers, 3 oilers, 12 firemen, 12 coal-passers, 3 water-tenders, 1 messenger, 1 storekeeper; total, 36.

A reduction of 16 men in the fire-room force is effected by oil burning. At sea she now needs but 3 firemen, but carried 6. This would reduce the force by 19 men.

Temperatures of fire-room seem to be about what one would expect in coal burning, but the temperature of the uptake and smokepipe gases runs high, the maximum being 925°, which shows an undue loss of heat here. The temperature of the oil in the settling tanks ranged between 68° and 100° F. on the trip out, and between 90° and 108° F. on the trip back.

The oil auxiliaries comprise 1 large oil pump, 2 small oil pumps, 2 oil heaters, 1 air-compressor, and 4 strainers.

There is a steam pipe connection to blow out the oil strainers, and another one to blow out the oil burners when clogged.

On August 3 the air-compressor needed overhauling, and steam atomizing was kept up during two and one half hours until the compressor was again working. During this time the evaporator supplied enough feed water to use 20 burners; the engines were not stopped while shifting from steam to air atomizing, and averaged 67.8 turns for the two and one half hours. They had before been making 70 turns. Also during the four days in port at Tahiti the forward main single-ended three-furnace boiler was used, atomizing with steam. Generally two burners in the middle furnace gave ample steam to run the following auxiliaries, all exhausting into the atmosphere, the boiler being fed with fresh water from the dock: Ice machine, dynamo, flushing pump, feed injector, two cargo winches, small portable steam pump, and steam for cooking, bathtubs, etc.

At first two firemen and a water-tender were on watch at a time, each fireman having one fire-room of six furnaces or twelve burners. The men had but little experience, combustion was poor, much smoke was made, much oil burned, and poor speed attained. To locate the responsibility for bad adjustment of burner valves, but one fireman was put on at a time to attend twelve furnaces (twenty-four burners). This made an improvement in the combustion.

Unfortunately, the top of the funnel can not be seen from either fire-room, and while the fireman can tell by the appearance of the flame as shown in the sight-hole, or even by the roar of the burner, when the combustion is perfect, in designing a boiler-room for liquid fuel the ventilators should be so arranged that the top of the smoke-pipe can be seen from each fire-room.

The work of the fireman would be even easier than it is and better results attained if the oil and air pressure is kept constant and the heated temperature of the oil constant. The apparatus then, once properly adjusted, would need very little change. To get these results is a mere matter of detail easily arranged. If the temperature of the oil rises it feeds more freely and a readjustment is necessary, and the same conditions hold with regard to the pressure.

It will be noticed that in addition to the independent oil and air supply valves the burners are fitted with an air plug cock and an oil plug cock connected to one lever, which then controls both oil and air supply, enabling the operator to shut them both off at once in emergency. At first when steam went up too high and a burner was shut down this lever was used; but shutting off the air thus gave the compressor less work, and as its governor was not sensitive the air pressure increased, making a readjustment of all oil and air supply valves necessary, with consequent smoke. Later on, when it was desirable to shut down a burner, the oil alone was shut off by the independent feed valve on the burner, and the untouched air valve kept the air-compressor's work more nearly constant; then when the burner was again required, the oil valve was opened and immediately lighted from the flame of the adjacent burner.

In starting fires with everything cold, steam is raised on the auxiliary boiler which burns coal, and the air-compressor, oil pumps, and oil heater are started. The oil is lighted by inserting oil-soaked rags in the air space surrounding the burner and touching a lamp to them, or an arrangement like a gas-lighter may be used.

Sometimes when the air pressure is too high, or insufficient oil is feeding, the flame flickers and may go out. If the oil is kept feeding under these conditions, on relighting there is a small explosion of the gases in the furnace, with a momentary back draft through the peepholes and ashpans.

When shut down July 19, for two and one half hours, plugging condenser tubes, one burner at each end of each boiler (four burners in all) furnished steam to run all auxiliaries, including feed pump, bilge pump, air-compressor, ice machine, dynamo, and flushing pump, all of which were exhausting into the atmosphere.

In the Grundell-Tucker burner the oil, heated by a steam coil under boiler pressure throttled down, passes through the inside pipe and is thrown out radially through the series of small holes. The air, first heated by compression up to 20 pounds, is further heated to a temperature of about 350° F. in the air chamber surrounding the burner, and called the air superheater. Air can be used at the temperature at which it leaves the compressor, and was so used on the trip down until July 17, when the superheaters were connected up. This air under the pressure of about 20 pounds surrounds the oil pipe in the burner and passes axially along the pipe until near the end, where it is given a whirling motion through small helical passages arranged like the rifling of a gun. It crosses axially and whirling through the fine oil streams spurting radially from the end of the burner, breaking up the oil into fine spray, the drops of which can be seen before they ignite. A further air supply (cold) is admitted through the hinged door of the ashpan, and is directed up across the path of the flame and heated also by a curved fire-brick wall built in the ashpan close to the front.

This ashpan door is not moved much, but the regulation of the air supply is by the valve control of the air and oil in the burner. The flame should be a steady, full, white or yellowish white one, filling the furnace.

The principal difficulties encountered were in the regulation of the supply of oil to the heaters by the pump and the consequent variation of the temperature of the heated oil and the freedom of flow through the burners. An automatic submerged float, arranged like a steam trap and fitted in the oil heater to control the throttle of the pump, failed to give good automatic results, and the supply of oil was regulated by hand. If the oil was heated too much (above 150° F.) some of the volatile gases are given off and mingle with the air pressing on top of the oil in the heater, thence passing with the air into the air superheaters and burners, the result being that on one occasion a heater got red hot from this cause.

Another difficulty was due to the choking of the strainers by foreign matter and impurities in the oil, shutting off the supply of oil, and on one occasion, August 10, putting out all the fires. Just previous to the fires going out, and while the usual air supply was on, and an insufficient amount of oil being fed, a dense white smoke like steam arose from the funnel. This strainer difficulty will be solved by fitting the strainers in pairs, so that a clean one can always be switched in while the choked one is being cleaned.

Generally the revolutions of the engines did not vary much during the day, and in calculating the horsepower for each day's average revolutions, when the cards for that day differed much, that set was selected whose revolutions were near the average for the day with the indicated horsepower, assumed to vary as the cube of the revolutions. If the two sets of cards for the day had the same number of revolutions their average indicated horsepower was used as a basis to compute the day's horsepower as before.

It will be noted that the log accompanying this report is kept from noon to noon. This was done as the patent log was inaccurate, and the speed of the ship was got from noon positions as given by sights.

It will be noted that speed was much higher on the return trip than on the outgoing, which is ascribed partly to the better combustion as the firemen got experience, partly to the overhauling of the bearings at Tahiti by the force on board, and mostly to the increased oil consumption allowed after the run down had proved that there was plenty of oil for the return trip, which was a matter of some doubt before, the ship being provided with coal for twenty-four hours to cover possible emergency.

Full power was not developed in the two boilers used, as schedule time was easily exceeded with from two to four burners shut off, though it would not appear, from the tabulated results, that the indicated horsepower would equal what can be got with a good system of forced draft. This burner, however, works well with the Howden system of forced draft, as seen on the tank steamer "George Loomis."

It must be remembered that the tabulated calculations are all based on the indicated horsepower of the main engines only, as it was considered better to use only data actually obtained, and afterwards estimated data, such as indicated horsepower of auxiliaries, could be applied without vitiating the observed data and results. No cards could be taken from any of the auxiliaries, but careful estimates give the following results:

Air-compressor, at 60 revolutions per minute	110	I. H. P.
Auxiliary feed pump and two oil pumps, one used intermittently	30	"
Dynamos	30	"
Ice machine	7	"
Circulating pump	5	"
Flushing pump	2	"
Baths, steam tables, evaporator, cooking, etc.	11	"
Total	195	"

The steering engine was not used except near port.

The size of air-compressor was based on the assumption that it requires one cubic foot of free air for every pound of water evaporated from and at 212° F., as shown by tests of various oil burners at Western Sugar Refinery, San Francisco.[1]

The weights of oil auxiliaries are as follows:

Air-compressor	9	tons
Two settling tanks	12	"
Two oil heaters	2	"
Two oil pumps (small)	½	"
One oil pump (large)	1¼	"
Fifteen superheaters (air) front	3.1	"
All pipes, valves, fittings, ventilators, etc.	8	"

It should be remembered that the boilers were designed for coal burning; that the oil-burning plant was fitted in a hurry, the machinists not leaving the ship until the gong rang for people to go ashore; that the firemen were without experience in oil burning, and that most of the automatic gear did not function properly.

With the air pressure constant; with the oil heated at constant temperature near 140° F.; with oil strainers arranged in pairs, so that one is always efficient, and with experience in firing, the results in economy of oil should be much better on the next trip; and the fireman's work, already very easy, will approach supervising automatic regulation. The fireman does not need strength nor previous training with coal. He should have a good eye, good ear, some common sense, and a desire to learn a new and easy trade.

In conclusion, I wish to state that every facility was given me by all the officers of the company, the chief engineer of the ship being particularly zealous in arranging for the taking of required data.

Very respectfully,

WARD WINCHELL,
Lieutenant, United States Navy.

Chief of Bureau of Steam Engineering,
Navy Department, Washington, D. C.

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[1] The eight tests made by the Liquid Fuel Board of the Bureau of Steam Engineering, in which air burners were used, consumed from 34.3 cubic feet to 78.3 cubic feet of free air per pound of oil, an average on the quantities of oil burned on the eight runs of 52.7 cubic feet, which at an average evaporation for these runs of 13.53 pounds of water per pound of oil, would be 3.9 cubic feet of free air per pound of water evaporated from and at 212° F.

TABLE 17. GENERAL SUMMARY OF LOG OF "MARIPOSA"—Voyage No. 1, from San Francisco to Tahiti.

DATE—1902.	Knots per Day.	Knots per Hour.	Revolutions per Minute	I. H. P., Main Engines Only.	Oil Used per Day, Barrels	Oil Used per Day, Tons of 2240 pounds	Oil Used per Hour, Pounds.	I. H. P., Main Engines, per Square Foot of Grate	I. H. P., Main Engines, per Pound of Oil per Hour	Square Feet of Heating Surface per I. H. P.	Pounds of Oil per Hour per I. H. P.	Pounds of Oil per Knot Run.	Knots Made per Ton of Oil	Knots Made per Barrel of Oil	Slip of Screw, in per cent	Actual Time
July 16	289	12.08	58.74	1,475	258	36.86	3,451	5.64	0.427	5.63	2.33	286	7.84	1.12	9.0	23h 55m
17	298	12.3	61.1	1,768	260	37.14	3,438	6.85	0.51	4.70	1.94	279	8.02	1.15	11.0	24 12
18	302	12.5	62.5	1,950	260	37.14	3,438	7.55	0.57	4.25	1.76	275	8.13	1.16	12.0	24 12
19	311	12.8	63.4	1,864	260	37.14	3,440	7.20	0.54	4.44	1.84	267	8.38	1.20	10.4	24 8
20	285	13.1	65.7	2,200	230	32.86	3,484	8.50	0.63	3.77	1.56	258	8.67	1.24	12.1	21 7
21	321	13.26	65.6	2,398	235	33.60	3,133	9.30	0.76	3.60	1.30	234	9.55	1.36	10.8	24 11
22	306	12.6	65.8	2,270	255	36.43	3,365	8.80	0.67	3.66	1.48	270	8.40	1.20	15.5	24 15
23	307	12.5	65.7	2,240	240	34.30	3,200	8.70	0.70	3.70	1.43	258	8.95	1.28	15.7	24 27
24	335	13.8	68.0	2,396	250	35.71	3,299	9.20	0.72	3.60	1.39	239	9.35	1.34	10.7	24 16
25	351	14.5	69.8	2,470	257	36.71	3,398	9.57	0.72	3.36	1.38	234.8	9.50	1.27	8.3	24 11
26	333	13.9	69.1	2,129	258	36.86	3,432	8.25	0.65	3.90	1.61	244.6	9.03	1.29	11.7	24 3
Total	3,438				2,803	400.43										262 57
Average		13.12	65.2	2,193	254.8	36.40	3,412	8.593	0.643	3.786	1.566	260.9	8.585	1.22	13.14	

REMARKS: July 20—Stopped 2¼ hours to plug leaky condenser tubes. July 25, 26—Jib and fore trysail set; trade wind port beam.

Voyage No. 1, from Tahiti to San Francisco.

DATE—1902.	Knots per Day.	Knots per Hour.	Revolutions per Minute	I. H. P., Main Engines Only.	Oil Used per Day, Barrels	Oil Used per Day, Tons of 2240 pounds	Oil Used per Hour, Pounds.	I. H. P., Main Engines, per Square Foot of Grate	I. H. P., Main Engines, per Pound of Oil per Hour	Square Feet of Heating Surface per I. H. P.	Pounds of Oil per Hour per I. H. P.	Pounds of Oil per Knot Run.	Knots Made per Ton of Oil	Knots Made per Barrel of Oil	Slip of Screw, in per cent	Actual Time
August 1	298	12.6	65.3	2,172	240	34.3	3,222	8.42	0.674	3.82	1.49	258	8.7	1.24	15.6	23h 50m
2	323	13.6	70.1	2,490	280	40.0	3,774	9.65	0.66	3.33	1.51	277.4	8.08	1.15	15.0	23 44
3	322	13.6	70.1	2,646	280	40.0	3,772	10.24	0.70	3.14	1.428	278.2	8.85	1.15	15.0	23 45
4	334	14.0	71.3	2,785	290	41.43	3,954	10.80	0.704	2.98	1.42	277.8	8.06	1.15	13.0	23 46
5	357	15.04	72.4	2,802	305	43.57	4,111	11.21	0.708	2.87	1.39	274.0	7.96	1.14	9.0	23 44
6	346	14.6	71.9	2,772	310	44.3	4,177	10.80	0.66	3.00	1.50	287.0	7.80	1.11	10.0	23 45
7	322	13.5	71.0	2,777	310	44.3	4,177	10.70	0.66	2.98	1.50	308.0	7.27	1.04	15.7	23 47
8	343	14.4	71.9	2,936	315	45.0	4,207	11.38	0.698	2.83	1.402	297.0	7.62	1.09	11.3	23 43
9	327	13.7	69.4	2,558	305	43.57	4,109	9.89	0.621	3.212	1.606	295.4	7.272	1.07	12.6	23 45
10	347	14.6	72.9	2,868	320	45.71	4,313	11.10	0.663	2.90	1.507	295.1	7.60	1.084	11.7	23 44
11	341.1	14.8	73.54	2,968	322	46.0	4,480	11.5	0.668	2.79	1.51	302.8	7.407	1.06	12.0	23 00
Total	3,660.1				3,277	468.14										260 31
Average		14.05	70.91	2,770	302	43.18	4,026	10.73	0.688	3.00	1.45	286.3	7.818	1.111	12.8	
Total knots	7,098.1				6,080											
Average two runs	3,549	13.58	68.05	2,461	276.4	34.29	3,719	9.661	0.665	3.393	1.508	273.6	8.201	1.165	12.97	

REMARKS: August 7—Strong head wind and sea. August 8—Wind and sea moderate ahead. Two double-ended boilers—Grate surface, 258 square feet; heating surface, 8,302 square feet. Average speed per day, 325.7 knots.

The Bureau of Steam Engineering has also received the following summary of the second voyage of the steamship "Mariposa" on the round trip between San Francisco and Tahiti. The data show that the oil consumption on the second voyage was considerably less than that on the first, due to two causes: Improvements in detail of the oil-fuel installation and increased skill and intelligence upon the part of the engine-room force.

The Oceanic Steamship Company is fitting an oil-fuel installation on the sister ship "Alameda," and it can be expected that when a spirited rivalry is created between the crews of the "Alameda" and "Mariposa" even better results will be forthcoming.

TABLE 18. GENERAL SUMMARY OF LOG OF O. S. S. "MARIPOSA."

Voyage No. 2, from San Francisco to Tahiti.

DATE—1902.	Knots per Day...	Knots per Hour.	Revolutions per Minute	Oil Used per Day, in Barrels.	Oil Used per Day, in Tons of 2240 Pounds ...	Oil Used per Hour, Pounds.	Pounds of Oil per Knot Run.	Knots Made per Ton of Oil	Distance Run per Barrel of Oil, in Knots...	Slip of Propeller, per cent...
August 21	328	13.3	63.7	255	36.43	3,400	248.8	9.00	1.29	7.0
22	297	12.3	62.6	225	32.14	3,000	242.8	9.24	1.32	13.4
23	282	13.3	64.0	210	30.00	2,800	237.4	9.43	1.35	9.0
24	330	13.6	65.9	235	33.59	3,133	227.9	9.82	1.40	8.8
25	310	12.8	62.0	220	31.43	2,933	227.1	9.86	1.41	8.8
26	311	12.8	62.0	210	30.09	2,800	216.1	10.37	1.48	8.5
27	292	12.1	62.0	220	31.43	2,933	241.1	9.29	1.33	13.8
28	305	12.6	62.1	220	31.43	2,933	230.8	9.70	1.39	10.3
29	305	12.6	62.2	220	31.43	2,933	230.8	9.70	1.39	10.5
30	322	13.3	65.0	230	32.86	3,066	228.6	9.80	1.40	9.5
31	326	13.5	66.0	240	34.28	3,200	235.6	9.51	1.35	9.4
Average, 11 days	309.9	12.96	63.4	226	32.28	3,013	233.3	9.60	1.37	9.9
Voyage 1, 11 days	312.7	13.12	65.2	254.8	36.40	3,412	260.9	8.585	1.22	13.14

Average temperature of uptake, 548°; average temperature of superheaters, 360°; average temperature of cold oil, 91°.

Voyage No. 2, from Tahiti to San Francisco.

DATE—1902.	Knots per Day...	Knots per Hour.	Revolutions per Minute	Oil Used per Day, in Barrels.	Oil Used per Day, in Tons of 2240 Pounds ...	Oil Used per Hour, Pounds.	Pounds of Oil per Knot Run.	Knots Made per Ton of Oil	Distance Run per Barrel of Oil, in Knots...	Slip of Propeller, per cent...
September 6	292	12.2	62.1	215	30.71	2,867	235.6	9.51	1.36	12.6
7	301	12.6	62.6	220	31.43	2,933	233.8	9.57	1.37	11.2
8	288	12.1	62.9	220	31.43	2,933	244.4	9.16	1.31	15.5
9	298	12.5	63.1	220	31.43	2,933	236.2	9.48	1.35	12.6
10	276	12.2	64.7	220	31.43	2,933	255.1	8.46	1.25	13.4
11	327	13.7	66.9	245	35.00	3,267	240.0	9.34	1.33	9.4
12	303	12.7	67.1	250	35.71	3,333	264.0	8.48	1.21	16.5
13	317	13.2	67.3	265	37.44	3,533	267.5	8.53	1.20	13.0
14	307	13.2	67.4	260	37.45	3,466	271.0	8.20	1.18	13.0
15	324	13.8	69.0	265	37.94	3,533	261.7	8.54	1.22	12.0
16	321	13.5	69.2	270	38.57	3,600	269.1	8.32	1.19	13.9
Average, 11 days	304.9	12.7	65.7	241	34.46	3,212	252.6	8.87	1.27	13.01
Voyage 1, 10 days	331.9	13.96	70.6	295.5	42.22	3,981.6	284.79	7.841	1.122	12.89

Average temperature of uptake, 546°; average temperature of superheaters, 360°; average temperature of cold oil, 90°

Steamer "Berkeley."—The bay and ferry steamers of the Southern Pacific Company burn oil exclusively, with the most satisfactory results. The change from coal to oil burning involved merely the building of tanks in the coal-bunker space, the installation of the necessary pumps, etc., and the substitution of checker walls for grates in the furnaces. As giving an idea of the cost of such changes, it is stated that the oil installation on one of the largest ferry-boats cost $1700 complete.

Through the courtesy of Mr. Wm. McKenzie, Superintendent of River and Ferry Steamers, Southern Pacific Company, it is possible to give a description of boiler-room and fuel-oil plant on the steamer "Berkeley," running between San Francisco and Oakland Mole.

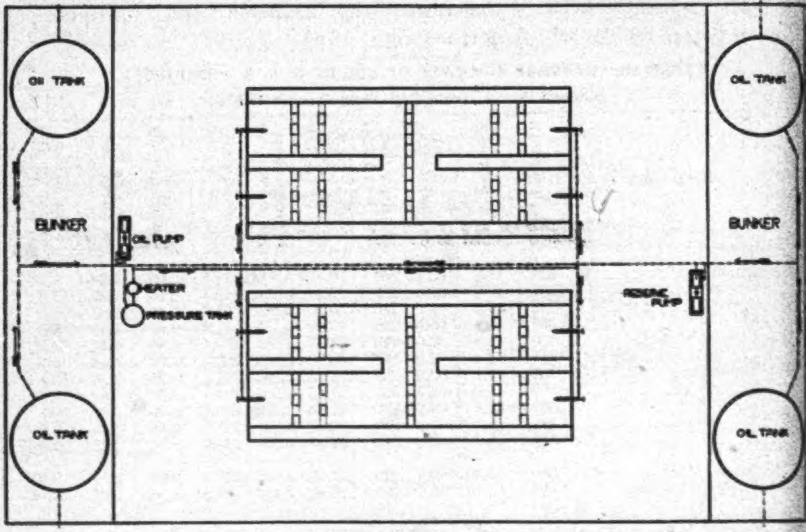


FIG. 42. Plan of Boiler Room, Steamer "Berkeley."

The "Berkeley" is a propeller boat of 1245 tons, length 260′, beam 40′, draught 8′ 9″, constructed in 1902 by the Union Iron Works. The propellers, one at each end of the boat, are 8′ in diameter, 14′ pitch, with 34 square feet of surface. The engines, constructed by the Union Iron Works, are triple expansion, the cylinders being 22″, 34″, and 56″ respectively, with 36″ stroke, using steam at 165 pounds in high pressure, condensing at 26″ vacuum through 1824 ⅝″ brass tubes, having 2475 square feet of cooling surface. They are handled by steam-operated link reversing gear.

The boilers are four in number, placed end to end in pairs, with continuous furnaces. Fig. 42 shows the general arrangement of boiler-room and oil connections. Boilers are internally fired, two corrugated furnaces to the boiler, the total heating surface being 4820 square feet. The Howden system of forced draft is used, air being forced by a fan through a series of pipes placed in the uptake, where it is heated to approximately the temperature of flue gases. The air pressure maintained is sufficient to balance the draft, water gauge on ashpit fluctuating somewhat, but showing on an average neither pressure nor vacuum.

Oil is stored in four upright cylindrical tanks, placed at ends of the old coal spaces. The bunkers, two in number, are 8′x 14′x 38′; the tanks, two to each bunker, are approximately 7′ diameter by 10′ high, and hold 2750 gallons each. They are of $\frac{5}{16}$″ steel, with flat bottoms and tops, the latter being tight, with gas outlet through side of vessel. They are connected in pairs with the main oil feed, the pipes entering tanks about one foot from the bottom, and being provided with independent valves to prevent passage of oil from one tank to another in case of listing or heavy rolling.

From the tanks, the cold oil passes to the pumps, of which there are two—one in use, the other held in reserve. The pumps are Knowles duplex piston pattern, 4½ x 2¾ x 4. The oil is discharged through a spring-governed regulator, by-passed into the suction, into the pressure tank, a cylinder about 18″ diameter by 5′ high. The air cushion in this tank is maintained by occasionally pumping in air against oil pressure, and takes up the pulsations of the pump, oil entering and leaving the tank from sides near bottom. From the pressure tank the oil passes to the heater, consisting of a cylinder 5′ high and 8″ diameter, with a single 1¼″ pipe passing up through the center, through which passes the exhaust steam from oil pump. The oil entering the heater at the bottom is heated to about 70° F. before being discharged from the top into a strainer of fine wire gauze, passing from the strainer to the main burner supply.

The burners are the "Little Giant," an inside mixing burner of the tubular type. The atomizing agent is steam at boiler pressure, 165 pounds, controlled by a globe valve; oil is taken to the burner at 45 pounds, and controlled by a lever-handle cock. The air supply enters furnace at top and bottom, and is controlled by a globe valve. As these ferry steamers make a landing and a ten-minute stop every thirty minutes, it is necessary that the fires should be readily stopped and started, and in practice a single movement of the oil cock lever, the opening of air valve, and a slight adjustment of steam supply, are all that is required, the oil igniting readily from the brickwork in the furnace, and the steam only requiring adjustment, and that very little. The oil supply is run steadily at full opening; if necessary to regulate the flow of oil, this is done, not by turning the lever, but by altering the width of opening of the cock, the oil passage through the plug being of inverted V shape, and regulated by an interior sleeve by which the orifice may be partially or entirely closed. It is thus possible to run always with oil cock wide open, while if necessary to alter the rate of flow for any reason, which seldom occurs, the adjustment may be readily effected from the outside, without stopping the flow or altering position of lever.

The furnaces are lined from end to end with a single course of fire-brick, extending half way up the side. About three feet back of the door is placed a checker wall of fire-brick, reaching rather more than half way up the furnace, and two feet farther back another wall of similar construction and height. The burner is entered near the bottom of firebox, and set level, the flame striking against and through the checker walls, the object being to distribute the heat more uniformly through the furnace than can be done with a naked flame. The boilers being fired from both ends have a common combustion chamber, but on installing oil burners this combustion chamber was divided by a light wall of fire-brick, placed crosswise, and reaching within an inch of top of chamber, thus making each boiler independent.

The experience of the Southern Pacific Company in the use of liquid fuel on steamers, as stated by Mr. McKenzie, has been entirely satisfactory. Labor has been decreased, dust from handling coal and ashes entirely done away with, fire-room temperature lowered (though temperature in uptakes is higher than when using coal), time in loading is diminished (the "Berkeley" oils but once in two days), and a great economy in fuel costs realized. Mr. McKenzie states that by handling and injecting the oil practically cold (the gravity is 14°) formation of carbon deposits in the firebox is entirely avoided, and that the greatest economy is had when a faint trace of smoke is rising from the stack. It has been shown in their experience that the loss arising from the slight waste of combustible gases incident to producing traces of smoke is much less than that due to the use of the excess of air necessary to secure complete combustion.

On the "Berkeley," and other steamers of the Southern Pacific Company, steam for the burners is superheated by means of a small coil of hydraulic pipe in the firebox. The temperature of steam as superheated is regulated by altering length of coil. They find it desirable to heat the steam to a high temperature, just below the point at which "starring" takes place. "Starring" is rather difficult to describe, although easily recognized by the eye. When it is taking place the flame, instead of being smooth and of even color, is filled with small sparks, or stars, due probably to the oil being heated by the steam above its vaporizing point, so that when ejected into the firebox and thus released from pressure, the drops actually explode, rather than burn. When "starring" is observed, carbon deposits are always found in the firebox, it is stated.

The experience of the Southern Pacific Company has been that the form of atomizer is the least important essential to success in oil burning, the adjustment of atomizer, of steam, air and oil pressure, and particularly of the form of furnace, to the conditions, being far more important. Many of their heaviest furnaces are equipped with home-made burners of the simplest construction, which they find entirely satisfactory.

Economy.—As bearing on the economy incident to the substitution of liquid for solid fuel in marine work, figures have been obtained in regard to the fuel consumption of seven steamers plying on the bay and rivers, showing the fuel consumption for corresponding months in 1902 and 1903, the steamers having meanwhile been changed from coal to oil burners. The data were obtained from official sources, and may be entirely relied on.

TABLE 19. FUEL CONSUMPTION ON BAY AND RIVER STEAMERS.

Steamer	No. Men in Fire-Room.		Saving in Wages of Firemen.	Fuel Consumed.				Miles Run.		Fuel per Mile Run.				Ratio of Cost.		Barrels Oil Replacing 1 Ton Coal
				Coal, 1902.		Oil, 1903.				Coal, 1902.		Oil, 1903.				
	'02.	'03.		Tons.	Cost.	Bbls.	Cost.	1902.	1903.	Tons.	Cost.	Bbls.	Cost.	Coal.	Oil.	
											Cts.		Cts.			
1	8	6	$140.00	460¾	$3.65	1488¼	$0.60	3322	2996	.1387	50.6	.4967	29.8	1.000	0.589	3.59
2	8	6	42.30	91	3.65	1224	60	825	2730	.1103	40.3	.4484	26.9	1.000	0.667	4.06
3	10	8	140.00	184 500	3.70 5.00	2559½	60	4261	4284	.1606	74.7	.5975	31.6	1.000	0.423	*3.72
4	10	8	59.60	204 108¾	4.00 3.00	2060	60	1703	4329	.1836	67.0	.4759	28.5	1.000	0.425	*2.78
5	......	......	......	91 271¼	3.00 3.75	1295¼	60	2353	2353	.1539	54.8	.5505	33.0	1.000	0.425	*3.46
6	......	......	......	395¼	3.75	1222¾	60	3635	3530	.1087	40.8	.3464	20.8	1.000	0.510	3.20
7	......	......	......	373¾	3.75	1180¼	60	3730	3635	.1002	37.5	.3279	19.7	1.000	0.524	3.27

*Average.

To bring the comparisons down to the plainest possible basis, we may take the cost per mile for coal in 1902, and for oil in 1903, and apply each of the figures to the number of miles run in 1903. Doing this we find that—

With steamer No. 1 the cost for coal would have been $1515.98, the cost for oil was $892.81; a saving of $623.17, or slightly over 41%, besides a saving of $140 for labor on the month's run.

With steamer No. 2 the cost for coal would have been $1097.19, the cost for oil was $734.37; a saving of $362.82, or over 33%, in addition to a saving of $42.30 on labor.

With steamer No. 3 the cost for coal would have been $3200.15, the cost for oil was $1353.74; a saving of $1846.40, or almost 58%, besides the saving of $140 on labor bill.

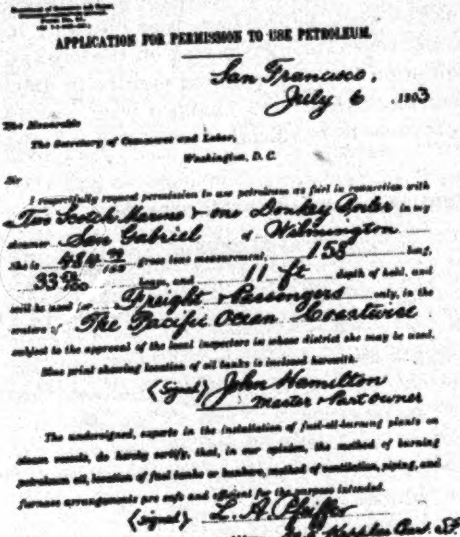
With steamer No. 4 the cost for coal would have been $2901.10, the cost for oil was $1234.05; a saving of $1667.05, or over 57%, besides saving $59.60 on labor.

With steamer No. 5 the cost for coal would have been $1289.44, the cost for oil was $776.49; a saving of $512.95, or 40%.

With steamer No. 6 the cost for coal would have been $1440.24, the cost for oil was $734.24; a saving of $706.00, or almost 49%.

With steamer No. 7 the cost for coal would have been $1363.12, the cost for oil was $716.10; a saving of $647.02, or almost 48%.

It should be remembered that each of these is the figures for one month only; also, that these steamers run on the bay, and are by no means of the largest. Yet the annual saving, on the basis of this month's run, would be from $22,156.80 to $4,353.84, and for the seven would aggregate $76,384.92.



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APPLICATION FOR PERMISSION TO USE PETROLEUM.

San Francisco,
July 6 .1903

The Honorable
The Secretary of Commerce and Labor,
Washington, D. C.

Sir:

I respectfully request permission to use petroleum as fuel in connection with Two Scotch Marine & one Donkey Boiler in my steamer San Gabriel of Wilmington. She is 484 72/100 gross tons measurement, 158 long, 33 92/100 beam, and 11 ft depth of hold, and will be used for Freight & Passengers only, in the waters of The Pacific Ocean Coastwise, subject to the approval of the local inspectors in whose district she may be used.

Blue print showing location of oil tanks is inclosed herewith.

(Signed) John Hamilton
Master & Part Owner

The undersigned, experts in the installation of fuel-oil-burning plants on steam vessels, do hereby certify, that, in our opinion, the method of burning petroleum oil, location of fuel tanks or bunkers, method of ventilation, piping, and furnace arrangements are safe and efficient for the purpose intended.

(Signed) L. A. Pfeiffer
Address: No 3 [illegible] S.F.

(Signed) J. R. Christy
Address: [illegible] Engineering Works S.F.

The undersigned, having made a personal examination of the above-named steamer and found that the arrangement for burning petroleum as fuel is exactly as described in blue print inclosed, do hereby certify, that, in my opinion, the arrangements are safe and efficient for the purpose intended.

(Signed) John Bermingham
Supervising Inspector. 1st District

July 6 .1903

The following paragraphs by Mr. J. B. Warner, Chief Inspector of Hartford Steam Boiler Inspection and Insurance Company, are reprinted from the 1904 manual of the Marine Engineers' Beneficial Association:

"**Installation of Oil-Burning Plants on Steam Vessels.** "—Owing to the large production of fuel oil on the "Pacific Coast at the present time, the owners of "steamers are looking very "favorably upon that product to take the place of "coal. About one hundred "and fifty steamers, varying in gross tonnage from 50 to 6000 tons, "have oil-burning plants installed, and are proving a success. Before "a plant can be installed in any steam vessel now under the super-"vision of the Board of Supervising Inspectors, permission must be "obtained from the Honorable Secretary of Commerce and Labor, and "Supervising Inspector-General, Washington, D. C., through the Super-"vising Inspector of the district in which the steamer is to be operated "and subject to the approval of the local inspectors of that district

"The local inspectors are furnished with blanks as shown on page 142, to be filled in and returned to them and the Supervising Inspector for their approval, after which the application is forwarded to Washington for final approval.

"When filing the above form of application with the local inspectors, a blueprint in *duplicate* must also be filed, giving three views of the steamer in which it is desired to install the plant, as follows:

"First—A side perspective view, showing the steamer at full length.

"Second—A cross-sectional amidship view, showing the location of the tanks athwart ship.

"Third—A vertical sectional or under-deck plan, showing the location of the tanks fore and aft.

"The capacity of each fuel oil tank must be plainly shown on the blueprint submitted.

"The shape of the tanks may be of any design best adapted to properly locate them in the vessel, if constructed of suitable material and workmanship, so that they will meet the approval of the inspectors.

"The shell plates should be of steel of good quality and heavy enough to prevent the seams being opened by the motion of the ship or surging of the oil in any weather. It is recommended that for ocean steamers the shell plates of the tanks be $\frac{5}{16}$" in thickness, and for inland steamers $\frac{1}{4}$" in thickness.

"The seams of large cylindrical tanks should be double chain-riveted, sheets laid close and well calked.

"It is also recommended that the rivet holes be drilled instead of punched. They will then be fair, and rivets can be driven to properly fill the holes to prevent leakage.

"It is often remarked by boilermakers and engineers that as there is to be no internal pressure applied to the tanks, any kind of a seam, if only single-riveted, provided it is tight, is good enough. This might be the case if the tanks were to be set up on shore and remain stationary. On shipboard, however, they are liable to be subjected to many strains and should be of a character that is above reproach.

"If the seams are double chain-riveted, they are, on account of the increased lap of the sheets at the joints, which greatly stiffens the tanks at those points, more apt to hold the sheets and calking edges tight when under lateral strains, than they would be if only single-riveted.

"In long tanks, suitable baffling plates should be put in and securely fastened to prevent the oil from surging. Under each tank there is required to be a drip pan. This should be of lead weighing not less than 8 pounds to the square foot.

"There should not be any openings cut in the bottom, sides or ends of the tanks; all inlets and outlets must be through the top.

"Reinforcing flanges should be of wrought steel and properly riveted "to the top of the tank for filling, suction, and vent pipes.

"All filling pipes should run to the bottom of the tanks, so that when "the tanks are filled the gas will be expelled through the vent pipes.

"The man-plate opening should be of ample size (11"x16" may do) "to facilitate getting into the tank for any purpose. The vent must "have an area equal to the diameter of the filling pipe, and should be "carried up above the superstructure of the vessel and have a non-"return bend on the end and covered with a fine copper wire gauze "screen.

"The question of crude oil for fuel and other purposes is a matter of "much concern to the public at large (especially so, in regard to its "safety on board steam vessels carrying passengers). It has engaged "the attention of Federal, State, and municipal legislators, with a view "to making laws for greater safety in the use of different grades of fuel "oils. In relation to the flash test of oil, it is a matter that should be "given much attention, for the reason that all oils are different as "regards the conditions under which they may be safely stored and "used for fuel; and as the conditions change with the variation of "temperature, the flash test must change accordingly; that is, the flash "point must be higher in accordance with the increase of temperature.

"The crude oils of California used for fuel purposes flash at from 85° "to 300° Fahrenheit, and fire from 138° to 540° F.

"For use on board of passenger steam vessels, an oil that will not "flash under 200° F. is indispensable, for the reason that the tempera-"ture rises in the engine-room and fire-room from 150° to 160°, and "sometimes higher in the tropics; and because oil, being a new fuel on "steam vessels and being handled in many cases by new and untrained "men, there can not be too many safeguards where the lives of the "traveling public are concerned.

"The laws of the Steamboat Inspection Service permit refined petro-"leum, which will not ignite at less than 110° F., to be carried *in cases*, "containing ten gallons each. In most instances, it is carried on the "upper deck and not in the hold of the vessel. If the same quantity "of oil that is often carried in that way were stored in bulk in the "hold, it might be very dangerous and a menace to life.

"The rules of the British Admiralty call for a flash point of 270° F.; "Lloyd's Register, a flash test of 200° F.; while the German authori-"ties accept 150° F. as a safe flash point.

"After many years of successful experience in the burning and "storing of oil for fuel, Lloyd's Register within the past few months "reduced the flash point test to 150° on all steam vessels classed by "them.

"With some exceptions, the experience with owners of steam vessels "has been that the question of economy has been considered too much "and that of safety too little.

"It does not appear unjust to ask the oil dealers to furnish affidavits "of the gravity tests, and of the flash and burning tests of oil sold to "the consumer, to be used for fuel purposes, so that proper judgment "may be exercised in its handling. If such affidavits had been furnished, some accidents that have already occurred might have been "obviated. In one case in particular, after a large steamer was destroyed, the flashing point of the fuel oil was proven to be only 85° F. "Had this fact been previously known, then, according to Lloyd's rules, "the oil would never have been placed in the steamer for fuel purposes.

"No fuel oil is allowed to be carried in the water bottoms under the "engine or boiler rooms on steamers.

"No passenger steamer burning oil as fuel will be allowed to discharge any oil from her tanks, as freight, at any port.

"Electric light fixtures and wires should be properly insulated and "free from danger of sparking near any oil tanks, or where there is a "possibility of gas accumulating. 'Davie' safety lamps should be provided for engineers in all cases, so that if the electric light plant is "shut down or out of order, they can be used in place of an open-flame "lamp.

"It is very important that suitable drip pans be provided, to be "placed under the burners and fittings; also under oil pumps and their "connections, to catch any oil that may leak, so that it can not reach "the bilges and skin of the vessel.

"If it is necessary to install an auxiliary or donkey boiler in connection with the oil-burning plant, it must be of tested material, and "is subject to the same inspection test, rules and regulations, as any "other boiler on board of the vessel.

"The permit as received from Washington, for oil burning on freight "vessels, requires that there shall be valves in the connection between "the immediate supply tank and the boiler or boilers, to regulate the "flow of oil at all times, and cut it wholly off when necessary, so that "the fires will be immediately extinguished; and where more than one "tank is used for storage of oil, and such tanks are connected with "pipes for discharging oil from one tank to another, there shall be stopcocks so arranged that they can be opened or shut from the deck of "the steamer.

"I would also recommend the above arrangement on passenger as "well as freight vessels.

"The laws as now laid down by the Department of Commerce and "Labor are liberal, therefore all due precaution should be taken to "install the plants as safely as possible.

"If many accidents should occur from oil-burning plants, the Gov-

"ernment and insurance companies would soon put such restrictive "measures in force that there would be no economy in using oil as fuel."

WATER-TUBE BOILERS.

While the water-tube boiler is much used in marine work, there is no necessary connection between the two subjects, the matter being placed here as a matter of convenience.

Aside from the well-known necessity of protecting lower tubes against the direct action of the flame, the burning of oil under a water-tube boiler does not differ in any particular from its use under a horizontal tubular boiler, although it may be said that an oil fire is particularly suited to boilers with very small water space, owing to the great steadiness of the fire tending to prevent priming and fluctuation in pressure.

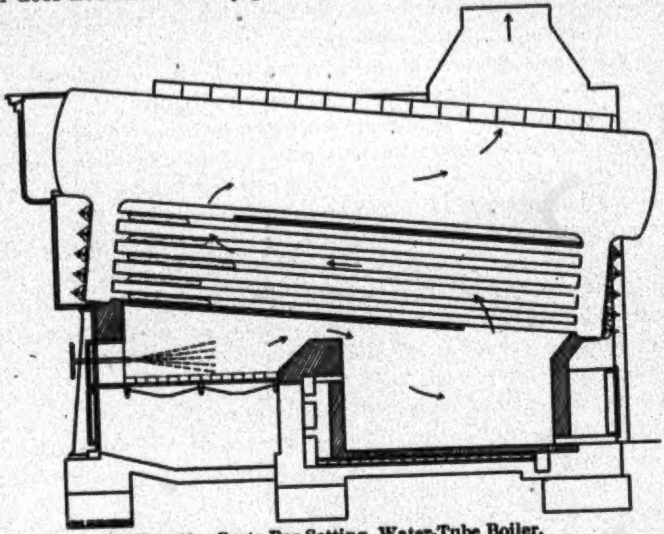

Fig. 43. Grate Bar Setting, Water-Tube Boiler.

The ordinary arrangement of firebox for oil burning is very simple, the grates being covered with a layer of fire-brick, checkerwise, and the burner introduced through front in such position that flame does not strike directly against lower tubes. In some cases the fire-bars are removed or omitted, and the burner placed in the ashpit. Fig. 43 illustrates the former method of setting, under a Heine boiler.

When the tubes pass into a mud drum placed back of ashpit it is a very difficult matter to so adjust burner as to avoid burning tubes. Even if properly set in the first place, the boiler may be injured by over-firing, or by carbon deposits partly choking nose of burner, thus deflecting the flame up against the tubes. To insure against this danger, an arch similar to that of a locomotive firebox is sometimes thrown over the flame. Fig. 44 shows this device applied to a National boiler.

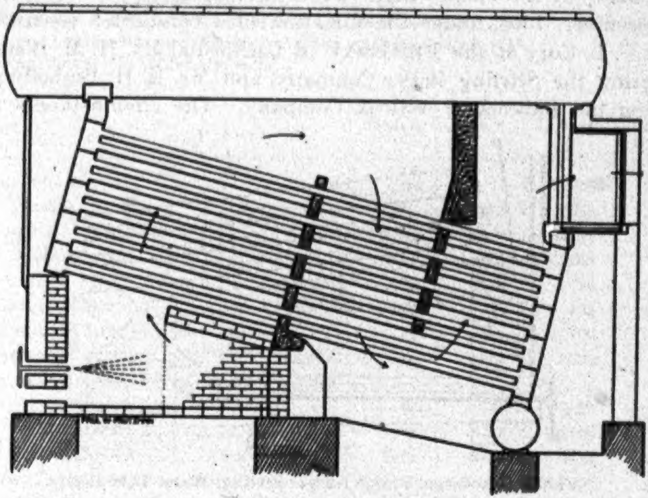

FIG. 44. Combustion Chamber Setting, Water-Tube Boiler.

Another means of securing the same result is to use a burner which throws the flame down instead of forward. Fig. 45 shows the Wilgus burner thus applied to a Stirling boiler.

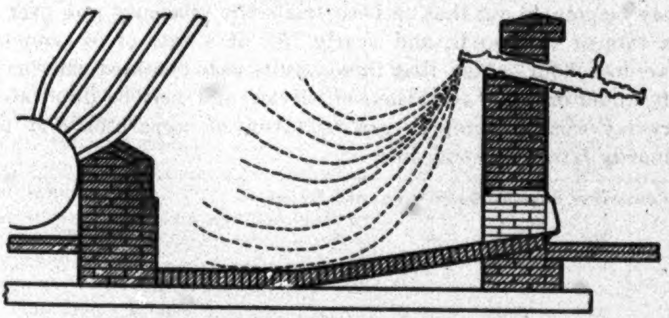

FIG. 45. Down Flame Burner, Water-Tube Boiler.

Still another method, though not by any means of universal applicability, is to place the burner in the back of the firebox, directing the flame to the front. The possibility of so placing the burner will depend on the arrangement of the rear portion of the boiler; at the best the improvement is slight. Fig. 46 shows this arrangement applied to a Babcock & Wilcox boiler.

Boiler Trials.—The tests summarized in Tables 20 and 21 below[1] were made by the Pacific Light and Power Company, at Los Angeles, in December, 1903, under the direction of a committee consisting of Prof. C. L. Cory of the University of California, Mr. H. M. Boon representing the Stirling Boiler Company, and Mr. E. H. Peabody representing the Babcock & Wilcox Company. The circumstances under which these tests were made render it certain that the figures are dependable in every particular.

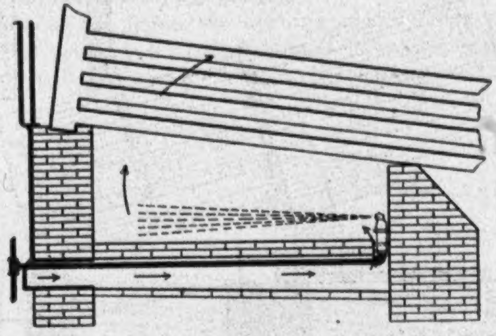

FIG. 46. Reversed Flame Burner Setting, Water-Tube Boiler.

The last test with each boiler was intended as a capacity test, and to reach so high a rate of evaporation as 7 pounds per square-foot hour it is necessary to sacrifice some essentials to the highest efficiency. Yet it may be pointed out that on both trials the efficiency was over 75% at a rate of 4½ pounds, and nearly 75% at a rate of 5¾ pounds per square-foot hour. Also, that these results were obtained with natural draft, under ordinary conditions of service, and may be duplicated in every-day work, if proper care be taken of apparatus and under ordinarily favorable conditions.

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[1] Courtesy of Chas. C. Moore & Co., San Francisco.

TABLE 30. BABCOCK & WILCOX WATER-TUBE BOILER.

Heating surface—4774.6 square feet.
Rated capacity—Builders' rating, 467 H. P.; Committee's rating, 477 H. P.
Oils used—
December 4—Whittier crude, 19°.
December 8—Mixture Whittier and Los Angeles crudes, 17°.
December 16—Mixture Whittier and Los Angeles crudes, 15½°.
December 21—Whittier crude, 19°.

		Dec. 4.	Dec. 8.	Dec. 16.	Dec. 21.
Duration of test *hrs.*		10	10	10	10
Steam pressure *lbs.*		156.4	156.2	156.9	157.3
Temperature of feed water *°F.*		62.65	62.54	61.10	60.92
Factor of evaporation		1.2050	1.2051	1.2067	1.2070
Pressure of oil *lbs.*		38	50	46	55
Temperature of oil *°F.*		100	124	132	111
Temperature of air in fire-room *°F.*		87	94	100	103
Temperature of escaping gases *°F.*		438	464	525	622
Draft	In flue, outside damper *ins.*	....	....	....	—.49
	Near damper, boiler side *ins.*	—.08	—.15	—.29	—.49
	In furnace *ins.*	—.02	—.04	—.12	—.15
Moisture in steam %		0.21	0.14	0.16	0.14
Total water apparently evaporated *lbs.*		152,850	179,233	232,113	281,630
Corrected for moisture in steam *lbs.*		152,529	178,982	231,742	281,236
Total water from and at 212° F. *lbs.*		183,797	215,691	279,643	339,452
Water per hour from and at 212° F. *lbs.*		18,380	21,569	27,964	33,945
Steam used by burners	Per hour *lbs.*	342.6	479.8	604.0	688.0
	Per pound of oil *lbs.*	0.295	0.332	0.300	0.290
	Of steam generated %	1.96	2.33	2.27	2.13
Specific gravity of oil used		.9417	.9529	.9637	.9407
Gravity by Beaumé scale *°Be.*		19.05	17.18	15.48	19.22
Moisture in oil %		1.06	4.62	8.71	0.42
Heat value of oil as fired *B. T. U.*		18,428	17,887	16,906	18,579
Heat value of dry oil *B. T. U.*		18,626	18,754	18,518	18,657
Total oil, as fired *lbs.*		11,507	14,442	20,127	23,906
Total oil, water deducted *lbs.*		11,475	13,774	18,374	23,806
Oil per hour, as fired *lbs.*		1,160	1,444	2,013	2,397
Oil per hour, corrected *lbs.*		1,147	1,377	1,837	2,387
Evaporation per hour per square foot heating surface, 212° F. *lbs.*		3.85	4.52	5.86	7.11
Horsepower developed		523.7	625.2	810.6	983.9
Per cent above rated power—					
	Committee's rating %	11.69	31.07	69.93	106.27
	Builder's rating %	14.08	33.87	73.57	110.69
Water evaporated from and at 212° per pound of oil—					
	Oil as fired *lbs.*	15.849	14.936	13.894	14.164
	Oil corrected for water *lbs.*	16.02	15.66	15.22	14.22
Efficiency		83.06	80.64	79.37	78.62

TABLE 21. STIRLING WATER-TUBE BOILER.

Heating surface—3287.8 square feet.
Rated capacity—329 H. P.
Oils used—
December 5—Whittier crude, 19°.
December 7—Mixture Whittier and Los Angeles crudes, 17°.
December 17—Mixture Whittier and Los Angeles crudes, 15½°.
December 19—Whittier crude, 19°.

		Dec. 5.	Dec. 7.	Dec. 17.	Dec. 19.
Duration of test	hrs.	10	10	10	10
Steam pressure	lbs.	156.0	156.4	157.0	156.3
Temperature of feed water	°F.	63.65	63.70	62.00	62.05
Factor of evaporation		1.2039	1.2030	1.2058	1.2056
Pressure of oil	lbs.	25	32	63	60
Temperature of oil	°F.	88	85	128	104
Temperature of air in fire-room	°F.	95	100	101	105
Temperature of escaping gases	°F.	454	517	606	720
Draft: In flue, outside damper	ins.	----------	----------	----------	—.66
Draft: Near damper, boiler side	ins.	—.14	—.20	—.25	—.34
Draft: In furnace	ins.	—.09	—.15	—.13	—.15
Moisture in steam	%	0.56	0.52	0.58	0.69
Total water apparently evaporated	lbs.	98,272	124,896	155,682	190,513
Corrected for moisture in steam	lbs.	97,772	124,247	154,779	189,198
Total water from and at 212° F.	lbs.	117,648	149,581	186,633	228,097
Water per hour from and at 212° F.	lbs.	11,765	14,958	18,663	22,810
Steam used by burners: Per hour	lbs.	383.7	387.7	444.4	456.8
Steam used by burners: Per pound of oil	lbs.	0.499	0.369	0.310	0.275
Steam used by burners: Of steam generated	%	3.42	2.72	2.50	2.10
Specific gravity of oil used		.9430	.9530	.9629	.9410
Gravity by Beaumé scale	°Be.	18.83	17.17	15.60	19.17
Moisture in oil	%	1.06	4.93	8.82	0.74
Heat value of oil as fired	B. T. U.	18,479	17,791	16,056	18,567
Heat value of dry oil	B. T. U.	18,677	18,714	18,506	18,705
Total oil, as fired	lbs.	7,764	10,577	14,361	16,585
Total oil, water deducted	lbs.	7,682	10,056	13,095	16,463
Oil per hour, as fired	lbs.	776	1,058	1,436	1,650
Oil per hour, corrected	lbs.	768	1,006	1,309	1,646
Evaporation per hour per square foot heating surface, 212° F.	lbs.	3.58	4.55	5.68	6.94
Horsepower developed		341.0	433.6	541.0	661.2
Per cent above rated power—					
Committee's rating	%	3.65	31.78	64.43	100.97
Builder's rating	%	1.79	29.42	61.48	97.36
Water evaporated from and at 212° per pound of oil—					
Oil as fired	lbs.	15.153	14.142	12.995	13.753
Oil corrected for water	lbs.	15.31	14.87	14.26	13.85
Efficiency	%	79.16	76.73	74.05	71.50

CHAPTER 12.

MINOR USES OF FUEL OIL.

By far the larger part, probably not less than ninety per cent, of the petroleum used for fuel is consumed in the generation of steam, on land or water. Yet the prospective importance of some of the lesser known uses of fuel oil is very great, not only from the standpoint of possible increase in oil consumption, but also from that of the cheapening of manufacturing processes, and the consequent encouragement of industry.

California is renowned as a producer of ores of the precious metals, many of these ores being sulphuretted and requiring to be smelted. Every reduction, even the most trivial, in the cost of smelting, makes it possible for the smelter to purchase ores of a lower grade, to the direct advantage of the mining industry.

The Pacific Coast has great stores of iron ores which, on account of the high cost of (imported) coke, can not be reduced at a profit, even though the local price of iron is high and the demand good. Much labor and thought have been devoted to search for a method of smelting iron ores by means of oil, without the use of coke or charcoal, and while it is probable that no thoroughly satisfactory method has yet been devised, a solution of the problem would be of immense importance to the iron-using industries of the Pacific Coast.

In the iron trades, oil finds considerable use, in ways which are often curious and interesting rather than important, except in a minor way. Some of the applications show very clearly the wide range of use to which fuel oil is suited, and its adaptability to unusual and difficult conditions.

In glass-making, and in the manufacture of brick and tile, both growing industries on this coast, the use of oil is extended and rapidly widening. Liquid fuel has practically made possible the manufacture of brick in the interior valleys, where wood is scarce and the cost of coal almost prohibitive. The successful use of oil in these industries indicates the high temperatures which may readily be had with oil fuel, and the close regulation of which it is capable.

Copper Smelting.—Crude oil fuel is used in copper smelting, where gold and silver are recovered, in the entire series of operations, from roasting the ore to melting the fine silver, except in the blast furnace and in melting the fine gold. The following paragraphs are taken (by permission) from an address delivered by Mr. Alfred von der Ropp, Superintendent of the Selby Smelting and Lead Company's works, before the California Miners' Association, in November, 1902:

"* * * Fuel oil for the generation of steam is not my subject, "and you are no doubt familiar with this problem. However, let me "state to you, that at the Selby Smelting and Lead Company's works "we use liquid fuel exclusively for the generation of steam, in Stirling "water-tube boilers, rated at 250 and 290 horsepower respectively. "We burn an oil of from 26° to 27° gravity, and evaporate, per pound "of oil, 14½ to 15 pounds of water, from and at 212° F. This gives you "a basis to figure the comparative value of oil with coal as a steam "generator. Another way of getting at the comparative values of liquid "fuel and coal is the following: In a large matting furnace of the "reverberatory type, it is considered that one ton of coal should smelt "about three and one half tons of ore. I find that in the same matting "furnace at Selby I can smelt one ton of ore with one barrel of oil; this "would give us three and one half barrels of oil to three and one half "tons of ore; or, in other words, three and one half barrels of oil are "equal to one ton of coal. One ton of good coal is worth today, in "San Francisco, we will say, $6. This means that one barrel of "oil at $1.71, or three and one half barrels at $6, would be equal in "effective value to one ton of coal at $6; and you all know that good "fuel oil can be bought today in San Francisco for one half of $1.71 "per barrel, and even less. In other words, you can save 50% and "more by the use of liquid fuel under the prevailing conditions and "prices for coal and oil.

"I wish to mention right now that I am not interested in any oil "wells or oil stocks, and am not attempting to boom liquid fuel.

"The following metallurgical furnaces use crude oil at our works at "Selby: four roasting furnaces, with a total of eleven burners; one "matting furnace, with three burners; one copper furnace, with one "burner; fourteen lead furnaces, with fourteen burners; thirteen zinc "retorts, with thirteen burners; three cupel furnaces, with three burners; "one antimony furnace, with one burner; one furnace for melting "fine silver, with one burner. Total, forty-seven.

"In all these furnaces, the use of crude oil has brought about a "saving of from 40% to 60% in the cost of fuel over coal. And this "does not represent all the benefits to be derived from the use of liquid "fuel in metallurgical establishments.

"Let me quote you a few simple chemical reactions that you all are "more or less familiar with, and which are of vital importance to all "metallurgical institutions.

"In the process of oxidizing sulphid ores, commonly called roasting "or desulphurizing, it is necessary that the atmosphere in the roasting "furnace should contain as much free oxygen as possible, to enable the "sulphur in the raw material to oxidize or burn off in the shape of "sulphur dioxid (SO_2) and sulphur trioxid (SO_3). In using coal as "fuel it is impossible to maintain this oxidizing atmosphere all the "time, because every time that fresh fuel is fed to the firebox, black "gases can be seen to fill the interior of the furnace, and during this "period of incomplete combustion the process of roasting, or oxidizing, "is completely at a standstill. What happens? A certain amount of "fuel and time is wasted, and nothing is accomplished.

"Now look at the ideal conditions prevailing in the roasting furnace "when liquid fuel is used. Once the flame is regulated by properly "adjusting the oil and steam inlets, we have a clear flame, with not a "trace of soot in the roasting chamber; and this ideal condition con-"tinues for twenty-four hours per day, enabling the sulphur in the ores "to combine with the oxygen in the air during every fraction of a "second. This means that we can crowd a roasting furnace using oil "far beyond the capacity of a furnace using coal, and still we can "produce a good end roast with the same per cent of sulphur remain-"ing. This means that we can reduce the cost of fuel, labor, and "repairs per ton of ore treated. In all metallurgical furnaces where "the aim is to oxidize, these same benefits are to be derived from the "use of liquid fuel. I quote you, for instance, the cupel furnace, where "the lead is oxidized to litharge, leaving the gold and silver on the "hearth, or test, as doré silver.

"But let me mention the matting furnace, of the reverberatory type. "In this furnace the roasted ore is subjected to a white heat to produce "a quick sintering and melting down of the charge. The aim in this "furnace is to produce, first: 'a copper-iron matte, which acts as an "accumulator for the precious metals'; and, secondly, 'a slag which "is formed from the earthy components of the ore.' As matte is a com-"pound of sulphur and the heavy metals (mainly copper sulphid and "iron sulphid) in fixed proportions, it is self-evident that the per cent "of copper in the matte depends on the amount of sulphur remaining "in the charge.

"Suppose, now, that we use coal as fuel in the matting furnace. We "will have a reducing atmosphere whenever the fireman gets busy and "fills the grate with fresh fuel, thus producing an incomplete combus-"tion for a certain length of time. During this period no sulphur can "be oxidized by the oxygen of the air. With oil we have an oxidizing "atmosphere during every second, and consequently we find that we "produce a higher grade copper matte in a furnace using liquid fuel "than we can possibly produce in a furnace using coal. On the other "hand, if it should be desirable to have the reducing atmosphere in "metallurgical work, it is easy to change from an oxidizing atmosphere "to a reducing one in an instant, by either choking the air inlet to the "furnace, or increasing the flow of oil to the burner. * * *

"As the dimensions of metallurgical furnaces are variable ones, you

“will readily understand
“that we need flames of
“many different sizes for
“our metallurgical tools.
“For instance, at Selby,
“the extreme lengths of
“flames used are 8″ and
“6′. In the zinc retorts,
“which are our smallest
“furnaces, we need a
“flame of 8″. In the
“large matting furnace,
“35′x16′ in the clear,
“we need a flame of 6′
“or even more in length.
“The burner has to be
“adapted to the furnace,
“and to the work to be
“performed. Hence, you
“will find at metallurgical
“establishments a
“great variety of burners,
“or at least a great
“variety of sizes of burners,
“and I know of no
“better all-round burner
“than the one formed of
“two concentric pipes,
“the smaller one being
“the oil pipe, and the
“larger one the steam
“carrier. By this arrangement
“the oil pipe
“is steam jacketed, and
“the temperature of the
“oil is raised to such a
“degree that its fluidity
“is very much increased
“and part of the lighter
“oils become gases. All
“this tends to break up
“more or less the viscous
“oil into minute particles,
“which ignite read-

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	a	b	c	d	e	f	B-B	C-C	H-H
No. 1	1 7/16	7/16	3/8	1/8	5/8	3/8	9/32	2 1/8	11/16	1/4	3/16	3/16	1/2	1/2	1	5/8	3/8	3/4	1 9/16	3 9/16	1 1/16	1 3/8	7/8	1 1/2	13/16	1 1/8	15/16	5/8	1/8	5/8	1	7/8	3/8″ Pipe Tap	1/4″ Pipe Tap	1/4″ Pipe Tap
No. 2	•	9/16	7/16	•	•	•	•	•	•	•	•	•	•	•	•	3/4	•	•	•	3 11/16	•	•	•	•	15/16	•	•	•	•	•	•	•	1/2″ • •	3/4″ • •	1/4″ • •
No. 3	1 1/4	3/4	1/2	5/16	3/4	•	1/8	•	•	•	•	•	•	•	•	•	•	•	•	•	1 3/16	1 1/2	1	1 5/8	1 1/16	1 5/8	1 1/16	•	•	3/8	1 1/8	1	3/4″ • •	3/8″ • •	3/8″ • •

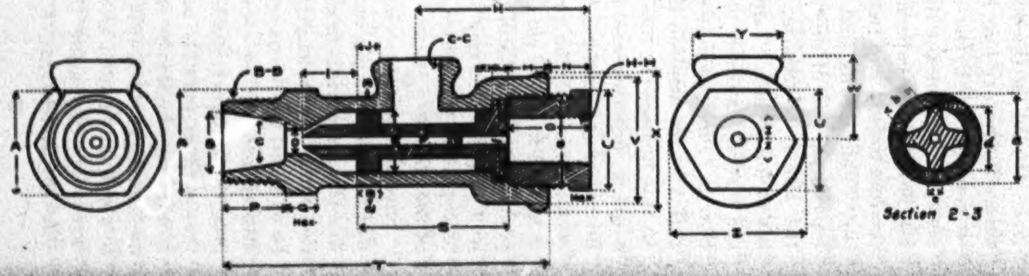

FIGURE 48.

OIL BURNER

USED BY

SELBY SMELTING AND LEAD CO.,

SELBY, CAL.

"ily when brought into contact with the oxygen of the surrounding "atmosphere.

"* * * During the last few years I have been repeatedly "approached by parties asking me why I do not use oil in the blast "furnace, and the only answer I can give them is the following: Solid "carbon plays a very important rôle, especially in the upper level of "the blast furnace shaft. Its function, especially with the fine ores, is "largely to limber up the charge and allow the flow of gases to penetrate the charge evenly; besides, incandescent carbon has certain "functions to perform in the blast furnace, which are of a chemical "nature, and which need not be discussed in this paper. If coke or "charcoal should be entirely replaced by oil in the blast furnace, the "blast furnace charge would very likely become too dense to allow the "combustion gases to escape freely. Besides, it seems to me, there "would be considerable danger from explosions if oil should be used as "fuel in blast furnaces. However, I think it may be possible to replace "part of the solid carbon fuel with liquid fuel, but I am not prepared "to state at this time what percentage of liquid fuel could be used, or "what mechanical arrangements should be introduced for the use of "liquid fuel in the blast furnaces."

The structural arrangements of metallurgical furnaces burning oil are, in general, very similar to what would be needed for solid fuel. The grates, etc., are of course dispensed with, and the burners introduced at points where flame is needed. A large number of burners of different types have been tried at Selby, but those now in use are of very simple construction, and give the most excellent results. In Fig. 48 is shown a sectional view of this burner. It should be pointed out that a light oil, such as used at Selby, in a very hot furnace, gives better results in so simple a burner than would a heavier oil in a smaller and cooler boiler firebox.

Glass-Making.—Through the courtesy of Mr. Edward Abramson, president of the Illinois-Pacific Glass Company, a representative of the Mining Bureau was permitted to see the application of fuel oil to the manufacture of glassware at that company's plant, where white, flint, and amber bottles and flint demijohns and fruit jars are manufactured.

The operations of bottle-making are simple enough in theory, though requiring great skill on the part of the workman. The raw materials for the glass (principally a California sand) are mixed dry, and charged into a melting furnace. From the melting chamber the semi-liquid melt runs into another chamber, from which it is withdrawn, at the working holes, in the form of a stiffly viscous paste. This paste, as is well known, is handled on the ends of iron rods or tubes, and in making machine bottles and jars, dropped into the mold, where it is pressed, blown, and shaped by practically automatic machinery.

Bottles, after being formed in the mold, have the neck shaped in a separate operation. For this purpose the necks are reheated to redness in a small furnace known as a "glory hole." The shaping being finished, the bottles pass to the annealing leahrs, where they are subjected to a mild heat, about 1200° F., for several hours, then allowed to cool very slowly, sorted and packed.

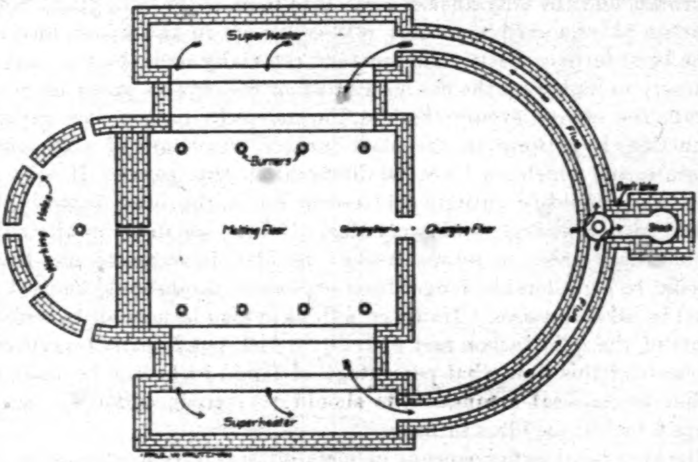
Superheater
Burners
Working Holes
Melting Floor
Charging Floor
Flue
Draft Valve
Stack
Flue
Superheater

Fig. 49. Glass Furnace, Burning Oil—Plan.

The glass furnaces vary in size, but approximate the proportions shown in Figs. 49 and 50. The raw materials are charged through the door *a* onto the floor of the furnace, the use of melting pots being unnecessary where oil is used for fuel. The burners ranged along the outer edge of crown throw the flame through small holes directly on the sand, which melts at a dazzling white heat, the glass thus formed running through the narrow slot *e* into the collecting chamber *c*, where it is kept at proper temperature by the burner at *f* in center of crown.

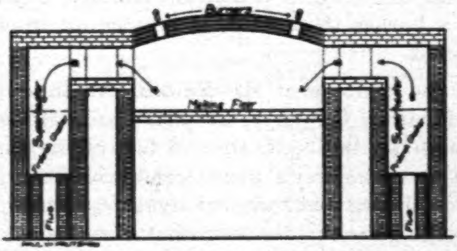
Burners
Melting Floor
Superheater
Superheater
Flue
Flue

Fig. 50. Glass Furnace—Cross-section.

At the sides of the melting chamber are the air-heaters, brick boxes filled to a varying depth with a checker work of fire-brick. The air for combustion passes up through one box, through the melting chamber, and down through the other box to the stack. In this operation the inlet heater is cooled, while the outlet heater is raised to a very high temperature by the fire gases from the melting chamber. At the end of an hour's run the order is reversed by means of a valve near the stack, the air now passing up through the heated box, the previously cooled box being again heated. In this way the air supplied for combustion in the melting chamber is always highly heated.

The effect of these checkers, however, is to greatly obstruct the draft, and that so rich a fuel as oil can be used under such circumstances shows its great adaptability to difficult conditions. In forcing a furnace of this kind, the pressure on the melting chamber is outward, the flame streaming out from every opening. Yet the consumption of the large amount of fuel required is effected without the formation of smoke or of noxious gases, the flame being perfectly clear and of great brilliancy. The advantages gained in this use of oil are numerous: saving in labor, and in wear and tear on furnaces, the operation becoming practically continuous, the removal of the expensive and fragile melting pots, ready and complete control over heats, and economy in cost of fuel.

The "glory holes" are small cubical boxes, about 12" in each dimension inside, a small opening being left in the walls, which are one thickness of fire-brick, near the bottom at each end. The flame enters through a hole in the top, strikes the bottom, and is discharged at the ends. These very small furnaces run at a low white heat, with great steadiness, and with very little noise.

The annealing leahrs are low, flat furnaces, the firebox being at the side, and the flame passing up through a flue and down onto the ware on the furnace floor. The most notable feature in connection with these furnaces is, that though run at a comparatively low heat, the bottles when removed after thirty-six hours' exposure to the fire gases are quite clean except for a slight cloudy film, showing that the oil is completely burned. This cloud, which is readily removed by wiping or by water, is of unknown composition, but from its white color when rubbed onto a dark surface, can not be soot. It may be due to deposition of sulphur-carrying compounds from the fire gases at the end of the heat, or more likely, from its salty taste, to the traces of salt always found in water accompanying crude oil. The cleanliness of the annealed ware shows very plainly the perfection of combustion, which is rather remarkable considering the low temperature and the length of time during which the glass is exposed to direct contact with the fire gases.

The oil-burning plant at this works consists of: four melting furnaces, with thirty-six burners; nineteen annealing leahrs, with thirty-five burners; fifteen "glory holes," with fifteen burners; one sand drier, with one burner; three boilers, with three burners. With the exception of those under the boilers, all the burners use air for injection, and are of the outside mixing tubular type, manufactured by the Cox & Sons Co., Bridgeport, N. J. They are set from ¼" to 3" above the holes through which flame passes, thus inducing considerable draft. Air is used cold, pressure seventeen pounds at receiver; the oil used is 20° gravity, pumped cold, pressure thirty-five pounds at pump.

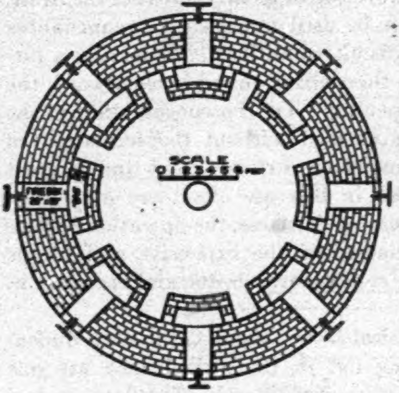

Fig. 51. Brick Kiln—Ground plan.

Brick-Burning.—Through the courtesy of N. Clark & Son, a representative of the Mining Bureau was permitted to examine the oil installation at their plant in West Alameda. At this factory fire-brick and sewer-pipe are burned in down-draft kilns, and terra-cotta goods in muffle kilns.

A down-draft kiln is of the general construction shown in Figs. 51 and 52. The flame from the burners enters the fireboxes, evenly spaced around the circumference of the kiln, passing into the "bag," a closed flue having the double object of protecting the goods nearest the firebox from the direct action of the flame, and of forcing the heat to the top of the kiln, so that it may pass down through the entire charge, instead of short-cutting to the flue. The latter is at the bottom of kiln, and communicates with stack by an underground passage.

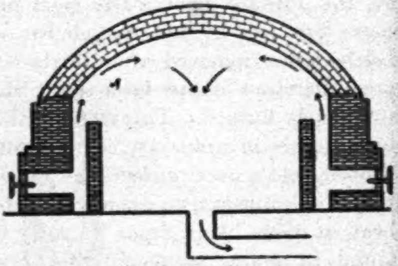

Fig. 52. Brick Kiln, Down Draft, Eudaly Pattern—Vertical section.

In starting a freshly charged kiln, it is necessary to fire very gently for several hours, as otherwise the product would be checked and spoiled by unequal expansion. The greatest difficulty in oil-firing occurs here; the firebox being completely cold and heating up very slowly, it is impossible to make the burners carry a steady flame when turned down as low as is necessary. To overcome this difficulty, the bottom of the firebox is formed into a drip pan, into which oil is allowed to flow slowly, burning in the pan. The gentle heat desired is thus obtained, and the inevitable soot deposited on the goods quickly burns off at a higher heat. When the firebox becomes sufficiently hot the burner proper is lighted, and the fire is then under perfect control. No difficulty is experienced in burning any quantity of oil desired, nor in obtaining the necessary degree of heat.

The burner is of the simplest construction, being formed of two concentric tubes of 6" length, the inner ¼", the outer ¾" pipe, both drawn in slightly at the end. Oil of 17° gravity is used cold or very slightly warmed, at forty pounds pressure, steam at ninety pounds. Attempts to use very heavy oil proved unsatisfactory, on account of lack of regulation, and heating of oil was abandoned because of the distance to which oil had to be pumped. It was found that the flow of heated oil varied greatly with slight differences of temperature, and that the pipes were likely to chill and shut off burner without warning.

Oil is used, at this plant, on ten down-draft and three muffle kilns, with a total of over one hundred burners, and gives the greatest satisfaction.

Pile Protection.—A rather curious use to which petroleum has been put is the coating of piles to preserve them from the attacks of limnoria. The general idea is by no means new, coal tar, asphalt, petroleum, and various paints and compounds having been in use for many years as pile preservatives, but the method of Mr. A. S. Cooper (Limnoriacide Company) below described is, so far as known, entirely different from anything of the kind before used:

"The following described patented invention is for the destruction of "limnoria and other marine bugs, worms, and insects and vegetation "infesting and growing on wooden bridges, jetties, piles, harbor works, "etc., and the future protection and preservation of these structures.

"A wharf or other structure to be treated, is surrounded by a floating dam. Within this dam is a suitable noxious substance of a specific "gravity less than water, so that it will float upon the water. The "escape of this substance is prevented by the floating dam. The dam "and noxious substance are raised and lowered by the tides and waves, "bringing the substance into contact with the piles or other structure, "thereby killing all life and protecting these structures from the coming of other worms, bugs and insects, and vegetation.

"Good noxious substances are crude, heavy, California petroleum "oil, which usually contains from 30% to 40% of asphaltum, or asphaltum dissolved in a distillate. The volatile parts of the heavy "petroleum or solution of asphaltum and a distillate, when spread on a "pile or other structure, gradually evaporate, leaving a coating of very "viscous liquid asphaltum, which adheres to the pile or other structure "with great tenacity.

"Poisonous materials may be added to oil or the solution, such as "creosote or carbolic acid, etc.

"Fig. 53 is a view of a wharf showing the floating body of noxious "material and the floating dam confining it about all the piles of "the wharf. AA is a wharf, the piles of which are surrounded by a "floating frame BB, which serves as a dam, to confine the floating sub-

"stance, represented by BD, so that the said substance covering the "water with a thin layer remains in contact with the piles.

"In Fig. 53 high water is indicated by the line CC. It will readily be "seen that by the constant rise and fall of the tide, and the ceaseless "action of the waves, the layer of petroleum oil confined by the floating dam will coat the piles between high- and low-water marks, being "that portion which suffers from the limnoria.

"The dam need not in all cases surround all the piles as a whole, for "as shown at G, Fig. 53, it may be applied about each single pile.

"AAA are timber floats and braces held in position by being "attached to half-circle hoops BB, these hoops being hinged together "at C. Around these braces and hoops is nailed a canvas covering "forming a canvas cylinder, opening at D. The "cylinder is opened and "placed around the pile "to be coated, and then "closed and tightly laced "together, as shown at "D, or it can be laced "with a double string, as "a shoe is laced. The "space between the canvas and the pile is then "filled with noxious material of less specific "gravity than water. "The floating dam and "noxious material are "lowered and raised by "the tides and waves, "coating the pile. The "necessary amount of petroleum oil is placed and the surplus removed, "when the dam is changed, by a large syringe.

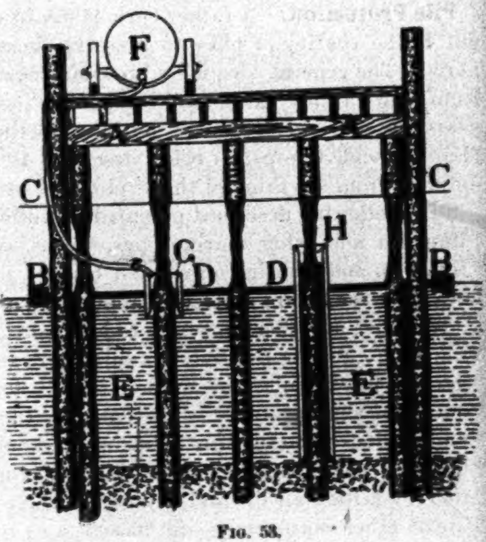

Fig. 53.

"A square box six inches deep, without top or bottom, if built around "a pile and left free to float up and down with the tides, makes a good "dam."

The creosoting process, many years in use for the purpose of preserving wharf and other timbers from the attacks of limnoria and teredo, and from decay, consists in saturating the outer layers of wood of the pile with heavy oil from coal tar. The piles or other timbers, loaded on iron cars, are run into a retort, a steel tube some 8′ to 10′ in diameter, and up to 110′ in length. The ends of this tube being closed with heavy iron doors, clamped on, hot oil is run in, and the temperature brought to the boiling point of the sap. The water vapor from the wood passes through a condenser to the vacuum pump, by which a high vacuum is maintained on the retort. The extraction of sap having been carried to the proper depth, and the pores of the wood thoroughly opened up by the boiling out of the sap, the vacuum is released, the retort completely filled with oil, and a high pressure applied by means of an oil pressure pump. Pressing is continued until the desired amount of oil has been forced into the wood, the lighter portions of the oil penetrating deepest, while the heaviest part remains as a hard black coating on the surface.

The oil consists principally of neutral hydrocarbons, of high boiling point, and considerably heavier than water, but contains also carbolic acid and other phenols, naphthalene, anthracene, and a number of other antiseptic substances.

This treatment, which greatly prolongs the life of the pile, acts in two ways: Rot is prevented by the antiseptic elements of the oil, also, probably, by the exclusion of air, while the pile is protected from the action of marine boring insects by the layer of densely saturated wood on the surface, which they can not penetrate.

The creosoting process is expensive, on account of the high price of creosote oil, and Dundon's "Petro-Asphalt Process" (used by the San Francisco Timber Preserving Company) aims to reduce the cost by substituting heavy crude petroleum, the mechanical part of the treatment being the same. The lighter portions of the petroleum penetrate the wood, while a hard asphaltic coating is left on the outside. The antiseptic properties of the creosote are largely lacking, but the coating offers an effective protection from air and water, and from attacks of insects.

CHAPTER 13.

PETROLEUM IN GAS-MAKING.

Petroleum and its products find extensive use in the manufacture of gas, and this use has been enormously increased locally, within the last few years, by the application of oil to gas-making processes which dispense with coal or coke. While gas manufacture has only an indirect connection with the oil industry, yet the consumption of petroleum for this purpose is now so large, and some of the applications so original and interesting, that a brief digression to this subject may be pardoned.

Illuminating gas may be made by dry distillation of almost all organic substances, and in the past gas has been made commercially from various fats and oils, petroleum products, asphalt, rosin and wood, but aside from a very limited use of wood, gas is now made entirely from coal, coke or anthracite with steam, and petroleum.

Coal Gas is made by distilling bituminous coal in fire-clay retorts, at red to yellow heat. The retort is a ⌓-shaped box of hard-burned fire-clay, some 3" thick, and about 16"x 22"x 10' in size. Five, six, or nine of these retorts are set in one fireplace, and constitute what is known as a "bench." The retorts project through the front wall of the setting, ending in an iron mouthpiece which is closed by a lid, clamped on and luted with clay. From the mouthpiece, a vertical standpipe conducts the gas into the "hydraulic main," a covered trough, where the standpipe is sealed in water and tar from the retorts. From the hydraulic main the gas passes to the condensers, where it is cooled and the tar deposited, and finally to the crude gas holder. By means of a gas pump or exhauster the pressure of gas on the retorts is balanced, a very slight vacuum being sometimes carried; by this means the leakage of gas through the porous walls of the retort is prevented.

From the crude gas holders, the gas is taken to the purifiers, where it is freed from sulphur compounds and from carbon dioxid, but as the purifying systems are common to all methods of gas manufacture, they need not be described here.

The retort is brought to the heat desired, varying from cherry red to lemon yellow, and is then charged with the proper amount of coal, perhaps four hundred pounds. The lid is then luted and clamped tight, and the evolution of gas commences. The heat drives off the volatile parts of the coal, which swells and partly fuses (in the case of a true coking coal) to lumps or even to a solid mass, leaving finally a residue of dry carbon, or coke. The proper time of heating, about four hours as a rule, having passed, the retort is opened, the coke raked out and quenched with water, and a fresh charge of coal introduced.

The composition of the coal gas, the yield per ton of coal, and the quantity of tar obtained, depend on the composition of the coal, the heat at which distillation is conducted, and the completeness with which the latter is carried out. Rich, fat coals naturally give more and better gas than dry coals, while a coal distilled at a low red heat will give a richer gas, a smaller yield, and more tar than the same coal distilled at a lemon-yellow heat. The first gas given off from the coal is the highest in illuminating power; as the distillation progresses the gas becomes poorer in light-giving constituents as the percentage of hydrogen increases. For these reasons the analysis of coal gas varies considerably according to circumstances, but an average analysis of "twenty-candle" gas is approximately as follows:

Methane	34.9%
Hydrogen	45.6
Illuminants	6.5
Carbon dioxid	3.7
Carbon monoxid	6.6
Hydrogen sulphid	0.3
Nitrogen	2.4
	100.0

Methane, hydrogen, and carbon monoxid furnish heat on being burned, but no light; *i. e.*, they burn with colorless or bluish flames. The light is furnished solely by the small percentage of "illuminants," while hydrogen sulphid and carbonic acid are removed by the purifying process to which all gas is subjected before being sold, and oxygen and nitrogen are indifferent bodies. The heating value of coal gas varies from 550 to 890 B. T. U. per cubic foot; that of the above sample would be 685 B. T. U. per cubic foot.

Water Gas is not made like coal gas, by destructive distillation, but by combining steam with incandescent carbon. Coke and anthracite consist, aside from the mineral matter of the ash, almost entirely of carbon, and this carbon, on being brought into contact with the vapor of water, at a high red heat, decomposes the water, taking over the oxygen to form carbon monoxid, and setting hydrogen free. The skeleton of this reaction is represented by the formula $C + H_2O = CO + 2H$, though the actual course of the reaction in the generator is probably not so simple.

The water-gas set consists essentially of a generator, where water gas is produced, a carburettor, where oil gas is produced and mixed with the water gas, and the superheater, where the oil gas is "fixed," that is, rendered permanent, so that it will not condense on cooling. The generator is simply a firebox of suitable shape, provided with means for introducing air blast and steam jets, and with an outlet into the carburettor for the gas. The carburettor is a box packed with fire-brick checker work, and provided with air blast and with an outlet into the superheater. The superheater is a similar box filled with checker work, and provided with air blast and with an outlet which may be turned at will into a stack, or into the gas pipe leading to the condensers. Fig. 54 on page 164 shows the general arrangement of such a plant, though it should be borne in mind that water-gas sets are made in many different forms, and that the figure shows only the general outlines.

In working this apparatus, a bed of anthracite coal or of coke is laid on the firebars, and blown to a bright red heat by means of the air blast, furnished by a blowing engine. The air in passing through the fuel not only raises its temperature, but also forms producer gas, which burns in the carburettor and the superheater, on being mixed with further supplies of air at these points. In this way the checker work in these vessels is raised to a high temperature, while the spent gases pass out of the stack, the stack valve being open while the valve in the pipe leading to condenser is closed.

When the necessary temperature is reached, the air blast is shut off, the stack valve is closed and gas valve opened, and steam is turned into the generator below the incandescent fuel. The steam coming into contact with the carbon forms water gas, which passes at a high temperature into the carburettor. Here it meets a supply of hot oil which is being sprayed over the checker, and oil gas is formed and mixes with the water gas, the mixture going forward to the superheater and then to the condensers. When the temperature of the apparatus falls too low for the steam to combine with carbon, and for the oil to be gasified by the checker work, the steam and oil are turned off, the stack valve opened, the air blast started, and the heating up recommences. The process is thus an intermittent one, the periods of heating up and of gas-making being usually about equal, and ranging from five to twenty minutes each.

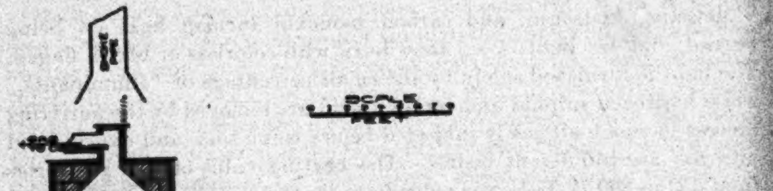

FIG. 54. Water Gas Generator, Merrifield-Westacott-Pearson type.

This apparatus performs two distinct functions: to manufacture pure water gas, and to mix this with oil gas. Pure water gas consists, in general, of the following elements:

Carbon monoxid	42.0%
Hydrogen	52.0
Carbon dioxid	5.0
Methane	1.0
	100.0

The heating value of a gas of above analysis would be about 330 B. T. U. per cubic foot.

These constituents all burn with bluish or colorless flames, and water gas is suitable for illumination only after being enriched by the addition of luminiferous elements. This process is known as "carburetting," and many methods of accomplishing the desired result have been tried, but at the present the method exclusively used on this coast is to produce oil gas in mixture with the water gas, as above outlined.

Petroleum of whatever nature may, by heating to the proper temperature and under the proper conditions, be almost entirely converted into permanent gas, and at the temperature of the carburettor of the water gas set, these gases are extremely rich in illuminating elements. The nature of this petroleum gas may be approximated from the following analysis of a sample of Pintsch gas, which is made by decomposing oil in iron retorts:

Hydrogen	18.4%
Methane	42.0
Illuminants	27.8
Nitrogen	11.8
	100.0

The heating value of this sample was 1320 B. T. U. per cubic foot.

The photometric value of the mixed gas will be generally proportional to the amount of oil used, though depending to some extent on the regulation of the apparatus. In California it was formerly the practice to use distillate exclusively, the distillate standard for this purpose having the following specifications:

Gravity	28° to 30° Be.
Flash point	150° to 180° F.
Distilling below 150° C.	1% to 15%
Distilling between 150° and 270° C.	50% to 80%
Residue at 300° C.	15% or less.

An oil of this character gives a stable gas, and a comparatively light tar. The quantity used varies with a great number of factors, but in making twenty-candle gas it is considered good practice if no more than five gallons of oil are used per thousand feet of gas, and to get this result requires care.

Some companies specify a lighter distillate, while others use crude oil of various gravities. Light crude, 22° or better, works very well, but the heavier oils are the source of some annoyance. The asphalt in these heavy oils is not gasified, but is largely carried forward into the tar, making the latter very heavy, and often causing troublesome stoppages. The quantity of crude varies widely, but in any case considerably exceeds the quantity of distillate which would be required to do the same work.

The manufacture of enriched water gas for illuminating purposes is by no means new, but was first put on a practical working basis by the inventions of Mr. T. S. C. Lowe, and is now very widely used in the United States and to a certain extent in Europe. Where bituminous coal is expensive, as it is on the Pacific Coast, enriched water gas can be manufactured at a considerably lower cost than coal gas, and in addition the installation, on a large scale, is much less expensive.

Because of the high cost of anthracite, or other hard fuel suitable to use in the manufacture of ordinary water gas, many attempts have been made to devise processes which will entirely dispense with solid fuel in gas-making, using oil exclusively. Many difficulties were met, and for a long time the problem remained unsolved, but during the past three or four years successful apparatus has been devised, and has now replaced water gas apparatus in over fifty towns and cities of the Pacific Coast.

The generator for the manufacture of what is known as "crude oil water gas" is very similar to that used for ordinary water gas; in fact, in one system the old apparatus is converted to the new use by constructing checker work in the generator proper and placing the oil burners (that is, the fire) at the top instead of at the bottom. But the greatest success appears to have been had with apparatus constructed specially for the purpose. In this apparatus, the generator, instead of a bed of fuel, has a fire-brick checker, which is heated by means of oil burners, carbon being at the same time deposited on the brick. The proper heat in generator and superheater being attained, the air supply is shut off, and steam and oil introduced, as in making ordinary water gas. The steam combines with the carbon on the checkers, forming water gas, while the oil is decomposed to form oil gas, which is fixed in the usual manner. The apparatus, like the usual water-gas set, is intermittent in its action.

The following particulars as to analysis of this gas, and the advantages of the process, are furnished by the California Light and Fuel Company, manufacturers of water-gas machinery using oil for fuel:

"As generally manufactured, to meet the demands of custom, this "gas is of from 20 to 22 candlepower, about 95% combustible, and con"taining from 650 to 675 heat units (B. T. U.) per cubic foot, and, "while it is an illuminating water gas in the ordinary acceptation of the term, its analysis shows its composition to be between that gas and coal gas, as will be seen from the following table, which gives average analyses of good qualities of these three gases, when made in a first-class and thorough manner, and when purified by iron oxid.

"The analyses show the seven constituents usually determined in ordinary observations:

Constituents.	Lowe Crude Oil Water Gas.	Ordinary Illuminating Water Gas.	Coal Gas.
Carbonic acid	2.0 %	3.0 %	2.0 %
Heavy hydrocarbons	10.0	11.0	5.0
Oxygen	.2	.2	.2
Carbonic oxid	7.0	22.0	6.0
Marsh gas	28.0	21.0	36.0
Hydrogen	48.0	38.0	47.0
Nitrogen	4.8	4.8	3.8
Total	100.0	100.0	100.0
Candle-power	20 to 22	20 to 22	16 to 17
B. T. U. per cubic foot (calculated)	662	621	655
Specific gravity, calculated (Air=1)	0.452	0.577	0.428

"The heating powers of the gases, as given above, are calculated from the thermal values of their various combustible constituents, as determined by the observations of Bertholet (see 'Calorific Power of Fuels,' by Poole, page 203), who gives the B. T. U. per cubic foot of those gases as follows: Carbonic oxid, 341; hydrogen, 347; marsh gas, 1073; and ethylene, 1712.

"In the foregoing analyses the heavy hydrocarbons are estimated as ethylene, as is the customary practice, and though this may, or may not, be a correct value for these gases (there being a variety of opinions on that subject), as all of the results given in the above table are calculated from the same factors, a fair comparison is afforded.

"The Lowe crude oil water gas process does not require the use of any special kind or quality of oil, any grade being entirely suitable for its use, either crude petroleum direct, or its distillates or residuums, but as crude oil is generally the cheapest its use is ordinarily advised. All grades and kinds are handled successfully and with facility, including Texas oils, and not excepting even the very heavy and viscous asphaltic oils of the Pacific Coast, some of which are of extremely low grade (about as thick as molasses), being from 12° to 14° Beaumé (specific gravity, 0.9859 to 0.9722), which grade of oil is successfully handled in no other gas-making system.

"The quantity of material necessary per 1000 cubic feet depends, of course, on the amount of gas made, the quality desired, and also somewhat on the grade of the oil; but, generally speaking, from 8 gallons per 1000 cubic feet in large works, to 12 gallons per 1000 cubic "feet in small works, are required, with intermediate varying amounts, "depending upon the size of works and average gas output, the quantity of materials stated also including the fuel necessary for steam-"making purposes. When using these amounts, the gas will have the "average composition given in the above table, when made in a skilled "manner, although better or poorer grades can be made at the will of "the operator by varying the quantity of material used.

"In addition to oil, gas-making expense is covered by the items of "purification, water, and labor.

"The item of purification is a very small one, the inexpensive iron "oxid method being entirely suitable, and as there is usually much "less sulphur in this gas than in coal gas, or in water gas made from "coal and oil, less purification is necessary.

"Water is used for steam-making purposes and also for condensing "and cleansing the gas, the amount used being about the same as with "ordinary water gas. This is usually a very small item of expense, as "it is the custom in most gas works to pump the water supply, and as "there is sufficient steam estimated upon for this purpose in the stated "amount of oil used per 1000 cubic feet, this item becomes insignificant.

"Labor can be much less in this process than in any other, as, there "being no solid fuels to handle, a gas-maker is able to accomplish very "much more work than with any other gas-making method. Skilled "labor is not necessary, as the operation of the apparatus is extremely "simple and easily learned, and any man of average intelligence can "master its working with moderate instruction."

CHAPTER 14.

OILED ROADS.

The necessity for road improvement in California is too apparent to need any argument. The Pacific Coast is a country of magnificent distances, and also a country of comparatively sparse population, so that while the importance of good roads to the welfare of the State is appreciated, the expense of putting and keeping the highways in order over long stretches of unsettled land is, or rather has been, prohibitive. The oiled road seems to offer the most feasible solution of the difficulty.

The principle upon which road oiling operates is the binding together of the loose particles of the surface into a compact and resistant, and yet elastic mass, by an oil of asphaltic nature, thus preventing the grinding of the road into dust during the long summer, and into mud in winter, and preserving the roadbed from the destructive effects of running water. To accomplish this result economically, the asphaltic residuum must be a considerable part of the oil, and must be tough, elastic, and cohesive, while at the same time proof against the effects of the weather. The crude oils of California are particularly suited to this use; in fact, it is probably safe to say that no other oils produced in quantity are so well suited.

Oil Sprinkling.—Any passable road may be rendered practically or entirely dustless by merely sprinkling with oil, leaving the mixing and compression to be done by passing vehicles. The disadvantages of this method are obvious: that it leaves the road surface covered with fresh oil, which is carried away on the wheels of vehicles and on the shoes of pedestrians, and that the surface when finally settled will be extremely irregular, pasty with excess of oil in one spot, dry and loose in the next. Yet even this simple treatment is much more effective than sprinkling with water, as it practically does away with dust, and as it is very much cheaper than either watering or proper oiling it has been and undoubtedly will be much used.

In Fresno.—During the summer of 1902 many of the streets of Fresno were oiled in this manner. The soil of this portion of the San Joaquin Valley is sandy, but also contains considerable clay or shale, so that during the long summer the unimproved roads become almost impassable from the depth of sandy dust, while the main roads, which have been graveled, have to be watered twice a day and then are dry most of the time. The oiling operation consisted simply in applying cold oil to the surface, with no attempt at mixing, rolling, or covering. The immediate result was a wide expanse of sticky black oil, which caused much complaint on account of being carried into houses and over carpets. But under the influence of the sun the surface oil soon soaked away, and while there were only occasional spots which had enough oil to be firm, the entire surface was cohesive enough to prevent dust from rising, and the condition of the road was, altogether, greatly improved, and at a very small expense. This method seems of doubtful economy in a city of the size and wealth of Fresno, but where long stretches of road over unsettled country are to be improved, it offers a means of considerably increasing the comfort and usefulness of a highway at small cost.

The same process has been much used by the railroads in California, a great many miles of roadbed having been oiled. It is customary in railroad work to apply the oil a little at a time, in several applications, allowing time enough after each for the oil to dry. In this way a coating of the consistency of asphalt is formed over the ballast, and dust is entirely laid, but it is well to remember that this crust is not subject to wear, and would probably be rapidly destroyed if traveled over by teams, as it has little solid foundation.

Complete Construction of Oiled Road.—It may be well to pass from the simplest form of road oiling, the mere sprinkling of the surface, to a description of the complete construction of a first-class road, as all intermediate grades of work would be carried out along the same lines.

Grading.—The first element in the construction of a good road, whether oiled or not, is to provide proper crown and gutters for drainage, to insert cross drains or culverts on side hills, and to secure proper elevation and sound foundation on low or marshy ground. These are problems for the civil engineer, and as they have been extensively treated by experts need not be dwelt on here. Suffice it to say that an oiled road, like any other, must be drained, and must have a foundation. An oiled road is very much like an asphalt pavement, in that the asphaltic or bituminous layer is merely a surface dressing; the road is underneath. It took the city of San Francisco many years to learn that a thin sheet of asphaltic composition spread over loose sand does not make a pavement. Further, a narrow roadbed, properly graded and oiled over the whole surface, is more serviceable and no more expensive than a wider road, necessarily of flatter section, and oiled in the center only. An eighteen-foot roadway will accommodate a very heavy traffic, while on long stretches with light traffic a twelve-foot bed is amply sufficient.

Wearing Surface.—We will suppose a roadway, say eighteen feet in width, to be properly graded, crowned from four to six inches, and drained where necessary. The next step is to provide the wearing surface. The bed material may be gravel, sand, sandy clay or loam, or adobe. If the bed is of gravel or of sand, the surface may be formed of the same material, or if of sandy clay, a good surface may be made if the sand approximates half the bulk of the soil. But if the bed is of adobe, it is very difficult to make of it a good wearing surface. If sand or gravel are to be had at a reasonable cost it is well to provide for a wearing surface of these materials over the adobe; if not available, a different treatment must be adopted, which will be described later.

Rolling.—Supposing that the materials for the bed are reasonably porous, the road should be thoroughly consolidated by rolling, unless this has been done by use. To facilitate packing of the material, the roadbed should be well wet down during rolling, as much water being used as the material will take without becoming too sticky. The rolling can hardly be overdone, in any case it should be continued until no further settlement is evident, and the surface is hard and smooth. If a wearing surface of foreign material is to be used, this is now placed, spread evenly, and rolled in the same manner. If the improvements are being made on an old road the procedure is practically the same, the old surface being loosened up, chuckholes filled, and the surface graded, wetted, and rolled with care.

Loosening.—We have now our road shaped and consolidated, but saturated with water, and it must be allowed to dry to a depth of at least two inches, or to the depth to which the later harrowing operations are to be carried. *On no account must the road be opened to travel while drying*, as it would thus be cut up and spoiled. Neither should the oil be applied until the road is dry, as oil will not adhere to a wet surface, nor penetrate a saturated mass. When dried sufficiently, the surface is loosened to allow the oil to penetrate. This is done with a harrow; the depth to which the loosening should extend is not entirely a matter of agreement among experts. It should not be less than two inches, and may be as great as four, and will depend to some extent on the nature of the bed material and on the probable firmness of the road-bed. If the bed is very firm and solid, only a thin layer need be loosened, as the bed can be depended on to carry the weight of traffic, and the oiled portion may be merely a wearing surface; but if the bed is incoherent, as in roads made over drift sand, the oil must be carried deeper, for in this case the oiled surface must take not merely the wear, but also the weight of the traffic. In any case the harrowing should be continued until the surface is thoroughly loosened and broken up to the required depth; a skilled man is necessary for this work, as the grade must be preserved and the surface left smooth and even.

Oiling.—The harrowing being finished the oil is applied. This is a very important part of the work, and several points must be considered:

The *quality of the oil* to be used will be spoken of near the end of this chapter.

The *quantity of oil* used will vary with the nature of the road material, coarse material taking more oil than fine, and with the depth to which the surface is loosened. Mr. T. F. White, a recognized authority, says:[1] "No rule can be laid down as to the quantity of oil to be "used, except to put on all the oil the road material will bear, without "being left in a sticky condition. This may vary from forty to one "hundred barrels per mile, per single width of the oiler (six feet), on a "newly oiled road. The first season of oiling a road is the most im-"portant one. On loose, sandy roads, two or three applications may "often be put on to advantage, the first season. The more oil that can "be incorporated with the road covering the first season, the less will "be required the next season, and still less thereafter. The streets "treated in Chino in 1899 took for the two applications made during "the season about sixty barrels per mile, per width of the oiler. In

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[1] From a paper by Mr. White, in "California Municipalities," 1903. Free use has been made of this and other papers by the same writer in the preparation of this chapter.

"1900 about half this quantity, in 1901 one quarter, and in 1902 none, "except on a narrow strip along the center of the streets, that had "become roughened up a little. This received a very light sprinkling, "followed by sanding. These streets are now like asphalt pavements, "and apparently will not need any oiling in 1903."

The *temperature at which oil is to be applied* (that is, the temperature of the oil) is a debated question. If the oil is heated, it is much more readily controlled, and can undoubtedly be spread more evenly than when applied cold. But on the other hand, the heating of the oil is the source of considerable expense, and it is rather doubtful whether the advantages gained compensate for the added cost. It was formerly assumed that oil applied hot would penetrate farther and faster than cold oil, but if we reflect that the oil makes but a very small part of the bulk of road mixture, and that the spray of oil as it falls must be chilled almost instantly to road temperature if the oil is hot, or raised to road temperature if cooler, it will appear that the temperature at application will make very little difference in the penetration. The tendency at present seems to be toward the use of the oil cold, and while considerable sums are invested in heating plants, most of the new work is being done with cold oil.

The *temperature of the road* at the time the oil is applied is a matter of great importance. The very heavy oils used in road work are barely fluid at 60° F., while at 110° they are much more limpid. It seems evident that if the surface material is hot and dry the oil will be greatly assisted in thoroughly saturating the mass, while if the road is cold and damp the oil is much more likely to lie in pools on the surface, or on harrowing to "ball up" into lumps coated with oil but dry inside. Oiling should always be done in summer, and on dry days, damp and foggy mornings being carefully avoided.

It is important, again, that the *oil should be evenly spread* over the surface, not left in patches, as may often be seen. Some ingenious devices to accomplish this result have been invented, but no machine will do away with the necessity for care on the part of the operator.

Mixing.—The oil having been evenly spread, it is now to be incorporated with the loose road material. In the city of Santa Barbara this is done by means of a "tamper, consisting of large iron teeth resembling exaggerated railroad spikes, set into a wooden cylinder." This seems like a very rational apparatus, as the teeth have at once a cutting and a lifting action, and as the grade is likely to be better preserved than by a drag harrow, the teeth being always buried to the same depth. Wheel harrows are also used and a special machine of this construction will be described further on. In any case mixing should be continued until free oil has disappeared, and until all lumps of dry material seem to be broken up and dispersed.

Finishing.—The road may now be rolled and opened for traffic, or better, it may be kept closed until the oil has had a chance to set. Rolling immediately after oiling is not very effective, as if enough oil has been used to make a good road, the material will have but little body. It should be remembered that the oil when freshly applied has no binding properties, but simply moistens the grains of road material, making a mixture analogous to stiff mud. The cementing property is developed by evaporation and oxidation of the liquid portion of the oil, by which the latter is converted ultimately into asphalt. Now if the surface is rolled immediately after oiling, it is smoothed down and consolidated so that air will have access to the surface only, and drying will be much retarded, while at the same time the surface has little stability and will quickly cut up under the wheels of vehicles. The surface has then to be reduced to shape by the traffic, which makes ruts and chuckholes almost inevitable. But if the loose oiled surface can be allowed to stand three or four weeks in summer, unused, before rolling, the air and light will have much more action on the oil, the latter will have time to penetrate thoroughly and to become partly hardened, and if then rolled will form a tough surface, which will roll smoother and stand considerable wear from the first without cutting. Of course, in many cases it is quite necessary to open the road immediately after oiling, and here it is probably better to roll before opening, followed if possible by a second rolling after some weeks' use. Before rolling, enough sand should be spread over the surface to take up any free oil, and this sand should be clean and sharp. When an important road is to be oiled it may be possible to work half the width at a time, turning the traffic onto the other half, and the oiled portion may then be allowed to stand long enough to get the very best results.

Reoiling.—The road is now finished for the time. No matter how carefully the work has been done, weak spots will always appear after a certain amount of use, and will cause no trouble if immediately attended to, but may be destructive if allowed to spread. After several months' use and after the surface has been raised somewhat by wear, but before the winter rains set in, another light application of oil is advisable, followed by just enough sand to take up the free oil. This helps greatly to render the road impervious to winter rains, if applied at the end of the dry season. Some oil will be required the next year; after that the amount of oiling will depend on the amount of wear and the nature of the road material. If incipient chuckholes are promptly filled with oily sand and rolled or tamped so that traffic will pass over rather than around them, an oiled road constructed as above outlined should last many years without other care than a slight amount of oil applied annually or biennially.

Roads in Adobe Soil.—When oiled roads are to be constructed from adobe soil, in such situation that absorbent material for top dressing can not be had, a different method is followed. The roadbed is formed, wetted, and very thoroughly rolled, and then allowed to become quite dry. The oil is then applied to the hard surface without harrowing or mixing, and best in two or three portions. After the last application, a very thin coat of sand, or failing anything better, dry road dust, is added, just sufficient to absorb the surplus oil, and the road allowed to stand for a short time before being used. No rolling is needed after the oil.

The rationale of this process is, that sand and gravel are incoherent when dry, and must be cemented together to a considerable depth by the oil in order to give a durable surface, while adobe, on the contrary, is very hard when dry, and so long as the surface is protected from wear, and water kept out of the foundation, the clay itself makes a good and strong road. It is only necessary, therefore, to form an asphaltic skin on the upper surface of the road, to take the wear of wheels and hoofs, and to keep out water, but this skin must be impervious to rain, and should be formed of several thin layers of oil applied at intervals. And as water from below has the same softening effect as water from above, great care must be taken to raise the roadbed well above water level in low ground, and to so gutter or tile sidehill stretches that water can not form pools on the uphill side of the road. If these precautions are taken, a very good road can be made over adobe ground with no other materials than a little sand for sprinkling; but if they are neglected, the oiling of an adobe road will not prove very satisfactory.

A Road in San Bernardino County.—Following is a description in detail of the construction of a stretch of road across a portion of San Bernardino County, under the direction of Supervisor T. F. White.[1] While some of the conditions met in this particular case are a little unusual, the general procedure is the same as would be followed in any case where first-class results were desired, and the description is of importance as embodying the result of much experience and expert knowledge.

The piece of road in question is one and one half miles in length, and was a new road, never before graded. Part of the road is through bottom land, with soil varying from loose sand to clayey loam, part around and up a hill, on a 4.5% grade. After the hill, the road encountered a piece of adobe soil, which works into deep, sticky mud during the winter rains.

The grading was done in the early spring, and the cost, especially in the hill portion, was heavy. A roadway forty feet wide, including ditches, was thrown up through the bottom, and a twenty-four foot roadway built around the hill. Through the bottom, which sometimes gets very wet during winter, the roadbed was thrown up to a good height, and crowned and well ditched to secure drainage, and rolled.

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[1] Communication from Mr. White to Mr. O. S. Breese, Field Assistant.

No. 30. Road Near Chino, Before Oiling.

No part of the distance had material such as would make a satisfactory roadbed for the large travel it would have to accommodate.

While grading over the hill a deposit of "oil sand" was struck, this being a disintegrated oil sandstone which is found in many places through these hills. This material had been tried the year before, on a bit of road and found excellent. It is sharp sand and gravel, with sufficient clay included to make it pack down firm and hard when properly heated, with good wearing qualities, and further it is a natural absorbent of oil. Without oil, however, it becomes sticky and cuts up

No. 31. Road Near Chino, Four Years Old—Three Oilings.

in winter. The deposit was uncovered, and the one and one half miles previously graded was surfaced with this material. This was done in the summer and early fall. The roadbed—the cuts and fills—had in the meantime become well settled and packed down. Stakes were set for a graveled way twenty feet wide, along the middle of the road. A blade grader was run over it, throwing the dirt out of this way to a depth of three or four inches, and forming a shoulder of eight or nine inches, on either side, for the surfacing material to abut against. Upon this foundation the gravel was spread, to a depth of nine inches in the center down to eight inches on either side. The foundation was watered, ahead of the spreaders, to keep it firm, and to cause the gravel to unite better with it. After the gravel was spread and smoothly shaped, the watering carts were started, and the road thoroughly soaked. That the water might wet it clear through, a heavy orchard cultivator was kept running over it while the water was being put on. This opened up the gravel, and allowed the water to go down through instead of running off. The cultivator was kept running until sufficient water had been put on, when the surfacing material had been worked into a homogeneous mass, of the consistency of mud for brick. The wetting down and stirring were done in sections of such length that each could be finished in one day, and the next morning a lever harrow was put on to smooth over and shape up the surface. This required a man with a good eye and some expertness, that the road might be gotten even and properly crowned. The harrowing was finished in the forenoon, and the weather being favorable to drying, the roller went on in the afternoon.

Though all these steps are important, the rolling is perhaps the most important of all. The roller used on this work weighed 1600 pounds per foot width, without loading, which is about right for the first two days, or as long as the road is at all spongy. As soon as the sponginess is gone, the roller can be weighted, conveniently with pig iron, until the weight is finally brought to 3000 pounds per foot. The rolling was continued from day to day until no further impression was made, and the surface was left hard and smooth.

After the roadbed had dried to the depth of two inches or more, the oil was applied, first sending out a man with rake and shovel to remove all manure or other loose material from the surface. The oil was applied hot, coming in this instance directly from the refinery, three miles distant, starting at a temperature of 250° to 300° F., and arriving at the work at from 200° to 250° F.

One hundred and twenty barrels of oil were applied per mile (late in the fall another light application was given). Two men with four horses did this work, putting on one half mile per day.

The total cost of construction of this one and one half miles closely approximated $1800, or about $1200 per mile. But as the grading and graveling were elements entering into the cost of any properly constructed road of this character, whether intended for oiling or not, the only cost over and above that of a common macadam road was that of the oiling proper. This cost was, 120 barrels of oil at $1.25 per barrel, $150, plus the cost of sprinkling, $15 per mile, or $165 per mile cost of oiling.

This bit of road, when examined in 1902, had been down two and one half years, had received one light coat of oil the year following its construction, and was still in good condition, though needing some oil for the year 1902. The quantity of oil used in the second application was not over one fourth the amount used in building the road.

Roads in Golden Gate Park.—Some of the roads in Golden Gate Park, San Francisco, have been oiled during the last two years, with most excellent results, the roads being very smooth and firm, closely resembling and in fact often mistaken for asphalt pavement, entirely dustless, and perfectly clean and free from mud during the long rainy season of the spring of 1904. The roads were originally constructed of "red rock," the hard metamorphosed shale of which the hills around San Francisco are largely formed, and by much use and constant attention have been brought into excellent condition. The object of oiling here was, not to make a road, but to preserve the surface, lay the dust, and prevent any formation of mud during wet weather. The following description of the method used is from the Thirty-first Report of the Park Commissioners of San Francisco, June 30, 1902:

"Previous to the use of oil on the drive, considerable trouble was "experienced, especially on the Main Drive, with the accumulation of "fine red dust. During the summer the prevailing winds carried this in "clouds, much to the detriment of the pleasure of driving and the "appearance of the plantations skirting the drive. To overcome this "a force of men was required to water the drives and lay the dust, while "in winter the formation of mud was unavoidable; but with the use of "oil these unpleasant features have disappeared. While possessing "many of the desirable features of bitumen, an oiled road is never "slippery or dangerous in wet weather, and the repair of road is com-"paratively simple and inexpensive. About six miles of drive have been "treated. As we are constantly in receipt of requests for information "on the method of preparation and application, the following is "appended:

"Before oiling, the roadbed should be carefully prepared, well graded "and shaped, and the surface smoothed and packed as firmly as possi-"ble. If the roadbed is dry to a depth of over one inch give it a thorough "soaking with water, and as soon as the surface is dry again apply the "oil as much in quantity as the material will absorb. This has reference to a road never oiled before.

"The roadbed being properly prepared, the next operation is the heating of the oil. Our system is to run a coil of steam pipe of two inches diameter placed in a four-wheeled sprinkling barrel of six hundred and fifty gallons capacity, with ordinary sprinkling attachment. Any sprinkler that is successful in distributing water will serve the purpose. We use two wagons—one on the road, while the oil in the other is heating. Steam for the heating of the oil is furnished from the boiler at the pumping station.

"The oil should be heated to a temperature of between 250° and 300° F. As soon as it is heated the horses should be started up and driven at a smart pace to the prepared roadway and the oil applied much the same as if sprinkling with water. A force of men follows with rakes to stir in the dust and allow the oil to penetrate the solid roadbed, as much oil being applied as the material will absorb. Should any pools form, sprinkle as much sand or dust as the oil will take up, stir with the rake and in a few hours the road will be ready for use.

"In oiling the road, whether for the first time or subsequent to previous oiling, we find it most convenient and satisfactory for carrying on the work, to close a portion of the roadway or to fix up one side of the road at a time, keeping the travel on the other side. When the side operated on is oiled and dusted, we turn the travel on that side while the other part is being worked. Under this plan little complaint is heard from the traveling public.

"Should the oiled surface wear through in spots, forming little depressions, all that is necessary to repair it is to take a common stable broom, sweep out the loose dust or gravel, fill the hole with a little oil, and spread enough dust or gravel to absorb it, care being taken not to apply too much, or the repaired portion will be found too soft and will require a second sprinkling of sand or dust to make the patch even with the main surface. We use a common hand watering pot for applying the oil in repair work.

"The oil we use is the heaviest we can procure and is from 14° to 16° gravity, and costs 72 cents per barrel delivered.

"About four hundred barrels are required to coat a mile of driveway sixteen feet in width."

Specifications for Oiling Streets in Santa Barbara.—The method of oiling used at Santa Barbara, in a rolling country with rather light soil, is shown by the following "Specifications for Oiling Streets in the City of Santa Barbara":

"Streets to be oiled shall first be plowed the entire width from gutter to gutter, to a depth of eight inches, and shall then be gone over with a harrow, disc or other suitable machine for breaking clods, until the "street is properly prepared for rounding up with the grader. All "stones shall be removed from the streets and deposited in the gutters. "After the surface has been thus prepared, the contractor shall crown "the street with a grader, to be furnished by the city free of charge.

No. 32. Oiled Road Near Santa Barbara.

"Any deficiency of earth necessary to give the street the proper crown "will be furnished by the city. After the street has been properly "crowned to the satisfaction of the superintendent of streets, it shall "be thoroughly wetted and rolled with a heavy road roller, until the

No. 33. Oiled Street in Santa Barbara.

"surface is unyielding. Depressions made by rolling shall be leveled "up with good earth and again rolled. When the street has been "plowed, graded, and rolled, it shall then be harrowed and the surface "loosened uniformly for a depth of four inches, and shall then be "sprinkled evenly with oil, heated to a temperature of 180° Fahrenheit. One hundred barrels of oil shall be used for each block, including one crossing. The oil shall be an asphalt base oil of from 12° to 14° gravity, and shall contain not more than 7% of water. After the oil has been sprinkled uniformly over the surface of the street, it shall be thoroughly tamped into the loose earth with a tamper, consisting of large iron teeth resembling exaggerated railroad spikes set into a wooden cylinder. This tamping shall be done until the oil and loose earth are thoroughly mixed and consolidated. The oiling and tamping shall be done only on days when the weather is warm and the sun is shining. After the oil and loose earth are thoroughly mixed and tamped, the surface of the streets shall be rolled with a heavy roller until the surface is uniform and compact." The balance of the specifications relates to damages, indemnities, and bonds, all as customary in such matters.

Roads in Kern County.—Facts and figures collected by the Department of Highways show that there are now in use in Kern County one hundred miles of such roads, and about forty-five miles of oiled streets in cities and towns.[1]

The first work of this kind by the Supervisors of that county was done in 1901. The roadbeds, varying from sandy to heavy soils, were first graded and rounded up slightly, and the oil applied to a width of ten or twelve feet, and then thoroughly mixed with a harrow. In applying the oil, use was made of an ordinary wagon tank with a sprinkler or distributor made of four-inch gas pipe, with half-inch holes drilled every two inches, the section of pipe used being about ten feet long. From seventy-five to one hundred barrels per mile were used on the first application, the sandy soil requiring the larger quantity to make a solid surface. After an interval of one or two weeks a second application of from forty to sixty barrels of oil per mile was made, the roads having been traveled in the meantime. The oil was applied in hot weather, artificial heating being considered unnecessary.

The oil used, varying in gravity from 12° to 15°, was obtained from the Kern River, McKittrick, and Sunset fields, at from 20 to 30 cents per barrel, the expense of each application to the roads being from 30 to 45 cents per barrel, in addition to the cost of the oil. From thirty to fifty barrels per mile have been used each year subsequently in maintenance and repairs, but this has been found cheaper than maintaining roads not oiled.

So satisfactory have the oiled roads of Kern County proven that arrangements are being made for the construction of about fifty miles more during this year. The level nature of much of the country and

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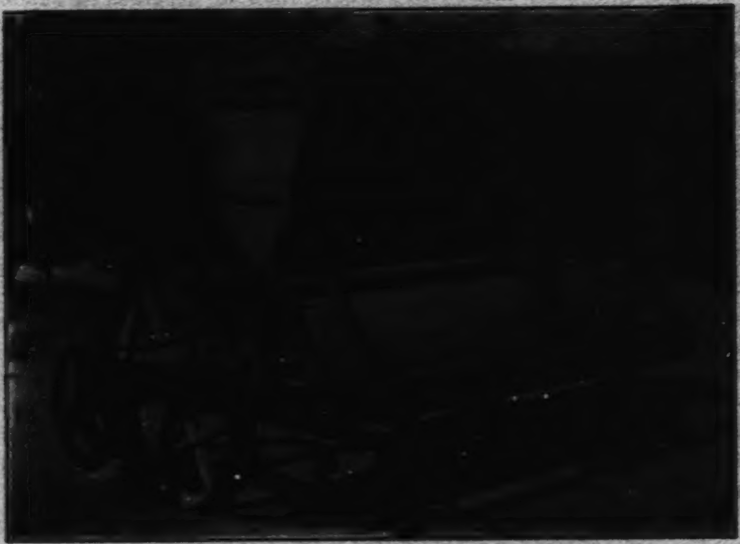
[1] Sacramento "Union," March, 1904.

No. 34. Road Oiling Machine.



No. 35. Road-Sanding Machine.

the nearness of the oil fields make Kern County particularly favored in the matter of oiled-road construction.

Quality of Oil.—The quality of the oil to be used in road work is a very important matter, as the success of the work depends to a great measure on the suitability of the oil. As already noted, the road-making value of the oil depends on the extent to which it is converted into asphalt, the latter binding together the loose grains of sand or other material into a tenacious mass, just as the asphalt of a city pavement binds the wearing surface into a smooth and solid sheet. The liquid portions of the oil have no value as a binder, so long as they remain liquid, their only effect on the road being to lay the dust for a time, as would water.

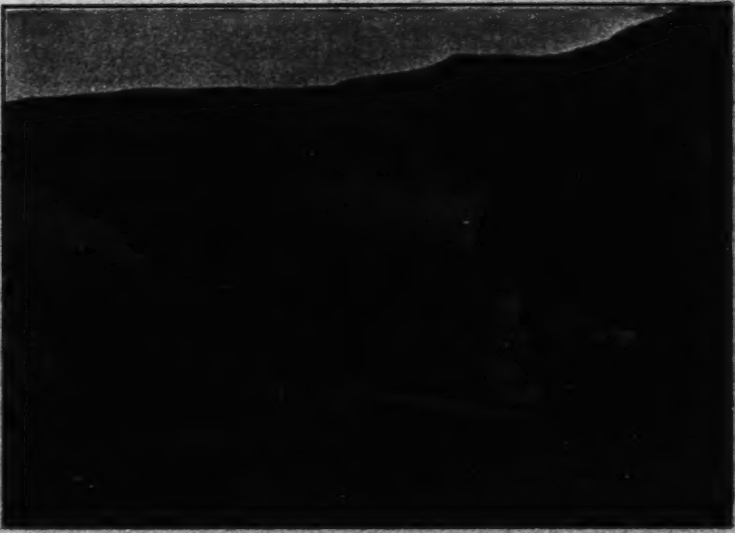
For the present purpose, the black (asphaltic) petroleums of California may be said to consist of two parts: a liquid portion, mainly hydrocarbons, and a small proportion of asphalt, from 1% up to 7%, dissolved in the liquid part. There are also bodies containing nitrogen, sulphur, and oxygen, but so far as the present subject is concerned, these may be classed with the liquid hydrocarbons.

When a crude petroleum of this nature is exposed to the action of air, it commences to thicken, and will gradually become sticky, then hard and glossy, finally dry and brittle, falling ultimately (in months or years) into a brown powder. This cycle of changes takes place more rapidly in dry than in moist air, more rapidly when warm than when cold, and much more rapidly in sunlight than in darkness or shade. The thickening is due to two causes: the evaporation of the lighter portion of the liquid fraction, and the conversion of the remainder into asphalt by the absorption of oxygen, or by the removal of hydrogen, which are much the same thing ultimately.

Asphalt in Crude Oil.—As the asphalt is the only portion of the oil valuable in road-making, the value of any particular oil for this purpose will depend on the percentage of asphalt originally contained, and also on the percentage of the oil converted into asphalt during the drying process. The percentage of asphalt originally contained is easily approximated by precipitating the asphaltene by means of gasoline, weighing, and multiplying by four, the proportion of asphaltene in "D" asphalt from oil being quite constant at about 25%. The percentage of the liquid portion which will change into asphalt on drying we can only estimate approximately, as to allow a sample to harden takes too long a time for practical testing, and we can not be sure that any forced evaporation gives the same results as would be had from spontaneous drying.

Testing.—Probably the best, certainly the simplest, test of the road-making value of an oil is to evaporate a weighed sample in an open

No. 36. Asphalt Mine, Carpinteria, Cal.



No. 37. Asphalt Mine, McKittrick, Cal.

metal dish, down to the hardness of commercial "D" asphalt, and weigh the residue. We thus get at once both the original asphalt and that formed during evaporation, and while it is not likely that the percentage of asphalt thus obtained is the same as would be gotten by allowing the oil to dry in the sun, yet it is highly probable that the comparison between different oils thus made is accurate. This test requires no apparatus except an iron or copper pan, a scale, and a plumber's fire-pot, though it must be admitted that the even grading of the asphalt requires care and a little skill.

The following results were obtained in testing a number of California oils, and two or three others, by this method, and show the wide range of values of different oils for this purpose:

TABLE 22. COMPARISON OF ROAD-MAKING VALUE OF CRUDE OILS.

No.	Source.	Gravity.	Asphalt.[1]	No.	Source.	Gravity.	Asphalt.[1]
		deg. Bé.	per cent.			deg. Bé.	per cent.
1404	Colorado	41.3	None.	2452	Coalinga	18.7	24.7
1400	Canada	34.9	None.	2432	Sargents	18.6	41.3
1407	Coalinga	33.3	Trace.	2462	Newhall	17.2	28.9
2441	Fullerton	33.0	19.1	2437	Midway	17.1	40.5
2438	Fullerton	32.8	20.4	487	Kern River	17.0	25.0
2402	Kansas	31.4	None.	2445	Fullerton	15.9	45.9
2426	Puente	28.0	26.1	2458	Coalinga	15.9	35.5
2442	Ventura	28.0	29.5	2453	Los Angeles	15.7	25.7
2433	Ventura	25.8	13.1	2440	Coalinga	15.7	30.4
486	Wyoming	23.7	33.7	2444	McKittrick	15.1	27.8
2434	Fullerton	23.3	36.5	2406	Kern River	14.3	48.5
2448	Whittier	23.1	23.3	1432	Sunset	14.1	29.2
494	Beaumont, Tex.	22.6	11.0	2454	Newhall	13.9	52.4
1421	Coalinga	21.2	25.0	2456	Los Angeles	13.0	42.2
2450	Whittier	20.4	30.2	2405	Coalinga	11.9	33.2
1462	Midway	20.2	22.0	488	Sunset	9.9	61.8
1403	McKittrick	18.9	22.6	2400	Santa Barbara	9.0	85.5

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[1] The figures in these columns are considered to be accurate to within three per cent.

Valuation.—These examples might be greatly multiplied, but the few here given are sufficient to show that the road-making value of the oil is very roughly if at all indicated by the gravity, and that the latter is not in any sense a proper test, as the percentage of valuable matter varies widely in oils of the same gravity from different fields, or even, in some cases, with oils from neighboring wells. The unsuitability of particular oils for road-making has been found, in a good many instances, by costly experience, but it would seem more rational to test all such oils as were available at reasonable cost in the locality where work is to be done, and to select the most suitable oil even at an advanced price. If an oil shows on careful testing (each sample should be tested twice, at least) say forty per cent of asphalt, to twenty per cent from another oil, it is safe to say that the forty per cent oil is nearly if not quite twice as valuable, barrel for barrel, as the twenty per cent oil, and would be more economical in the long run if it could be delivered for less than twice the price. Fortunately the oils most suitable to use in road-making are, in general, those of least value for other purposes, and can as a rule be had at the lowest market price, so that intelligent examination of the oils offered will often save money, not only in the long run, but even on the immediate cost of the material.

Dirt in the oil is no drawback, except that it is valueless and displaces its bulk of oil, unless so much be present as to clog the outlets of the distributing machines. Water also is permissible up to a reasonable amount: up to five per cent or even more it does no harm except to displace its bulk of oil. The percentage of water and of sediment is easily found by the test given for fuel oils in Chapter 4.

Residuum.—The residuum from petroleum refineries handling California oil is, if sufficiently reduced, often very suitable for this use. It should be tested as a crude oil, and has the same value in relation to its percentage of asphalt. In some situations it may be had within carting distance of work to be done, and if charged into wagons at a high temperature will retain its heat, in warm weather, for several hours.

CHAPTER 15.

CALIFORNIA'S OIL-REFINING INDUSTRY.

The business of refining petroleum, while of many years' standing in this State, having originated in 1856, has come into commercial prominence only within the last few years. Ten years ago there were in California but two refineries worthy of note, that of the Pacific Coast Oil Company at West Alameda, and that of the Union Oil Company of California, then lately removed from Santa Paula to Rodeo. During this time the former institution has been merged in the Standard Oil Company, which has removed the plant to Point Richmond, where it has been reconstructed on a much larger scale, while the latter plant has also been much enlarged and improved. In addition, other plants have from time to time been erected, until there are now within the limits of the State some thirty-four oil refineries, with a gross still capacity approximating 37,500 barrels, all of which plants, with possibly one or two exceptions, are now in successful operation.

Oil refining in California is divided into two very distinct classes: the refining of light oil for the production of the usual line of products, as made elsewhere; and the distilling of heavy asphaltic oil, the production of asphalt being here the main feature. The former operation uses the lightest oil obtainable, the larger the proportion of volatile elements the more profitable being the handling. On the other hand, the latter operation seeks the heaviest of the crude oils, or rather those containing the largest proportion of asphalt, the distillates in this case being of very little commercial value. Between the heavy asphalt oils and the light "refining" oils there is an intermediate class, ranging roughly from 16° to 20° in gravity, which are little if at all refined. As is well known, the gravity of a crude oil is only the roughest indication as to its value for refining, and the limits above given must be taken in a very general way, there being a number of crudes falling within these limits which are of some value for refining purposes. As the two classes of refining operations mentioned above are essentially distinct, it may be better to consider them separately.

Light Oil Refining.—The lighter crude oils of California are divided into the usual line of products: several gasolines and naphthas or "distillates," the latter being, in this sense, a cant term applied to naphthas lying between benzine and the burning oils, and ranging in gravity from 56° to 40° Be.; burning oils; "stove oil," a straw to amber colored oil of 35° or lower, used for fuel in gasifying stove burners; paint oils, used for adulteration principally, and other special products in this class; gas distillates, of 30° to 28° gravity, used in carburetting water gas; fuel distillate, of 28° to 24° gravity, used as fuel in the same manner as crude oil; and the lighter lubricating oils. Some difficulty has been experienced with the heavier lubricants, and the paraffin products are entirely absent. The residue is, in almost all cases, of an asphaltic nature, and in only a few works is it converted into coke.

The following table exhibits a list of the commoner products of petroleum, as made in this State, with remarks as to quality, market conditions, and price. As to the latter, it should be noted that the figures given are only a very rough approximation, it being very evident that current quotations, local conditions, quality of goods, and a dozen other factors will influence the price received for any of these articles:

TABLE 23. LIST OF REFINED PRODUCTS.

	Degrees Be.	Price—Cents.		Quality.	Remarks.
		Per Gallon.	Per Barrel.		
Gasoline	68	16		The best	Market excellent.
Benzine	62	13		The best	Market fair.
Engine Distillate	56 to 40	7 to 10		Excellent	Made in many grades and sold under many fancy names. Market good and increasing.
Kerosene	44 to 42	14		Good merchantable.	Market good.
Kerosene	42 to 40	?		Fair to poor.	Some export market.
Stove Oil	35 to 32	4 to 5		Satisfactory.	Market much oversupplied.
Gas Oil	30 to 28		100	Good	Demand decreasing.
Fuel Distillate	28 to 24		60 to 100	Good	Some market at price given. Large outlet at price crude oil.
Neutral Oils	24 to 22	6 to 10		Good	Small market.
Light Lubricants	24 to 20	8 to 14		Good	Fair and growing demand.
Engine Oils	20 to 18	14 to 20		Good to fair.	Fair market, growing steadily.
Cylinder Oils	18 to 15	20 to 50		Poor	Do not, as a rule, meet market requirements.
Crude Lubricants, Car Oil, etc	17 to 15	2½ to 5		Good	Demand oversupplied.

Asphalts, of various grades—about $14.00 per ton—market rather oversupplied, but rapidly increasing.

Qualities of Commercial Products.—The **Gasolines** produced in California are undoubtedly of the very highest grade. With the exception of the heaviest engine distillates, they are strictly water-white, and hold their color well. The odor is sweet and ethereal, the odor of the lighter grades reminding strongly of sulphuric ether, and they are free from the offensive after-odor of the gasolines of Pennsylvania. They volatilize freely, and leave very little residue when passed in quantity through vaporizers. At the same gravity they boil at a lower temperature than Eastern gasolines, and volatilize more rapidly when exposed to the air, the difference in favor of the Western gasoline amounting to from 2° to 4° in gravity; that is, a California gasoline of 68° gravity will approximate the same boiling range and speed of evaporation as a Pennsylvania gasoline of from 70° to 72° gravity.

Engine Distillates can be distinguished from the gasolines only by an imaginary line; the lightest distillates, prepared for small engines, automobiles, etc., run well up into the sixties in gravity, while the heaviest are intended to replace kerosene in engines prepared especially for that fuel. As a rule, they are less rigorously treated than gasolines or kerosene of the same gravity, and they differ, in the lower members from kerosene, in that no attention is paid to flash point. The lighter distillates are usually nearly or quite water-white, but some of the heavier distillates are turned out in standard white shades, there appearing to be but little difference in their actual value where identical except as to color. On account of their greater specific gravity they have a slightly higher fuel value than Eastern gasolines, and because of a higher carbon percentage require a little more air to secure perfect combustion.

Kerosene.—It is generally admitted that the burning oils prepared from California crude are not of the highest quality. While the color can be made entirely satisfactory, and the odor is sweet and if anything less unpleasant than that of Pennsylvania kerosene, the burning qualities are not equal to those of the best Eastern oils, the flame being less white, and there being more tendency to smoke and to crust the wick. These faults have been variously ascribed to sulphur, to nitrogen, even to silica (!), and to asphalt remaining in the finished oil, but there seems some reason to think that the trouble is due rather to the nature of the hydrocarbons constituting the body of the kerosene. As there has been much argument on this subject, it would be in poor taste to insist too strongly on an opinion, but it may be pointed out that the amount of sulphur found in the best California kerosenes, by combustion, is extremely small; that it has not been shown that the presence of sulphur in any amount would cause smoking and yellowness of flame; that the nitrogen is entirely removed in the acid treatment; and that asphalt is a non-volatile substance, not likely to be present in a distillate unless by accident. On the other hand, it is evident from mere consideration of the relation between specific gravity and boiling points of California kerosene, that the hydrocarbons making up the body of the oil are of entirely different nature from those found in Pennsylvania kerosene, and it has been shown by other methods that these hydrocarbons contain a larger percentage of carbon and a smaller percentage of hydrogen than do the hydrocarbons in the Eastern oil. As the amount of air required to burn an oil completely increases with the increase of carbon percentage, the excess of carbon in our local oils explains the tendency to yellow or smoky flame, the color of the flame indicating merely that the air supply is insufficient to completely consume the oil.

If it be true that the comparatively low grade of local kerosene is due to the nature of the hydrocarbons of which it is composed, rather than to the presence of impurities, the evil probably does not admit of any remedy, as no chemical treatment would alter the constitution of the oil itself. It is probable, however, that a great deal of the trouble met with California kerosene in the past has been due to imperfect refining, substances having been left in the oil which could and should have been removed. Where California kerosene is properly refined it is of good second quality, not equal to the best of the Eastern oils, but fully equal to the oils from various sources sold under the general name of "bulk oil." Further, the difficulty is largely one of adjustment of air supply, and as the market becomes accustomed to local oil, as it will with increasing output, there is every reason to suppose that our product will be used with entire satisfaction to the consumer. A great change for the better in this respect has taken place within the last three years, the output of kerosene on the Pacific Coast having largely increased, and with this increase of output the prejudice against local oil has greatly diminished. A large proportion of the oil now used in California is supplied by local refineries, and it is probable that within a few years almost the entire market will be so supplied.

Gumming or incrustation of the wick may be due to several causes, but the one most likely to bring about this result is the attempt to run too heavy a distillate into the kerosene. The oils running at from 37° to 35° gravity may often be forced into the kerosene without lowering the gravity of the finished article below 42°, but these oils are so little volatile that they have a strong tendency to decompose in the wick, from the heat of the flame, without completely gasifying. This decomposition forms a body similar to asphalt, and ultimately carbonizes the wick, stopping the flow of oil, and thus lowering and distorting the flame. The remedy is to cut the kerosene within narrower limits, either raising the gravity, or keeping the gravity even by cutting out an equivalent part of the lightest portion. Gumming may also be due to imperfect removal of the original impurities in the oil, or to decomposition of the oil by overheating after treatment.

California kerosene as now turned out by the better class of refineries is a water-white oil, of a sweet odor, gravity from 42° to 44° Be., viscosity about 1.10, flash point from 111° to 122° F., burning point some 10° to 12° higher. As a rule, it distills within considerably narrower limits of temperature than does Eastern kerosene.

Lubricants.—The lubricating oils prepared from California crude are of rather uncertain status as to quality. The lighter oils appear to be very satisfactory, but the heavier oils do not seem to have been able to take their proper place in the market. The color and odor are satisfactory; the flash points are low as a rule; the viscosity may be produced as desired, but rapidly decreases with rising temperature, this being, indeed, the principal objection to their use; the cold test is very low. The following table shows the principal characteristics of several California lubricating oils. It should be noted that no two refineries turn out their lubricating oils according to exactly the same specifications, and that for this reason the figures given for each grade are suggestive only. These oils are all pure mineral stocks.

TABLE 24. PROPERTIES OF LUBRICATING OILS.

OIL.	No.	Gravity °Bé.	Viscosity at 60° F.	Viscosity at 185° to 200° F.	Flash. °F.	Fire. °F.	Cold Test. °F.
Ice Machine	2486	23.1	4.2	1.1	334	361	—12
Spindle	1416	21.5	9.5	1.2	309	356	Below 0° F.
Dynamo	2487	21.2	12.2	1.2	354	406	1
Machine	456	19.5	14.6	1.6	335	380	Below 0° F.
Engine	1415	19.2	30.5	2.1	378	430	15
Engine	2489	19.4	103.7	2.3	430	471	20
Cylinder	1442	13.5	25.2[1]	1.9	455	515	28

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[1] At 100° F.

It will be noted from the above figures that these oils lose their viscosity almost completely at from 185° to 200° F., and if this property is, as is highly probable, inherent in the nature of the hydrocarbons, it can not be overcome. But against this property must be set the low cold test, and the attendant ease of manufacture. While it is possible that, for some uses, the oils of the Pacific Coast will never be suitable, there seems no reason why, when properly prepared, they should not be entirely satisfactory for all ordinary purposes. Though there has been, and is, much prejudice against these oils, the output is growing steadily, and it seems almost certain that in time they will take their proper place in the market. It is doubtful whether an entirely satisfactory cylinder oil can ever be made from these crude oils.

Heavy Distillates.—The products intermediate between kerosene and the lubricating oils are of uncertain properties. Stove oil, a heavy kerosene, is made to a certain extent, for use in gasifying burners in household and hotel stoves and ranges. A great number of devices for this purpose have been placed on the market, and a few of these have had a small measure of success, though it must be admitted that the search for a really satisfactory burner for household use seems to have advanced very little during the past three years. These devices are all difficult to regulate and to keep in order, they all produce more or less smoke, and are liable to sudden and annoying failures. In large restaurant and hotel kitchens, where strong fires are kept going continuously, they are more satisfactory, as the skill available for regulating and keeping them in order is generally of a higher class than in a private family.

Distillates for gas enriching have been used to a large extent, but during the last two years the demand has diminished considerably, owing to the introduction of processes using crude oil. Chapter 13 gives some details as to this subject.

The distillates sold or used for fuel are generally mixtures of oils otherwise unsalable, and the characteristics naturally vary somewhat widely. In general they run from 24° to 28° gravity, and should flash at 120° F. or above. They are an excellent fuel. Some attempts have been made to use them in gasoline engines equipped with generators, such as are used with Coalinga crude oil, but without much success, owing to the difficulty of gasifying them completely.

Out of this general fraction are also worked oils for spraying plants, used for this purpose both straight and in emulsion with other substances, and various neutral oils for paint-mixing, etc. The total demand for oils of this class, aside from fuel distillates, is very small.

"Refining Oils."—As noted above, California crude oils are divided into two classes: those suitable for refining for light products, and those unsuitable for refining, or useful only for asphalt production. The refinability of an oil is a matter of comparison only, all our oils producing some products more valuable than the crude, and there being nothing to prevent the refining of any of them, if the percentage of valuable elements justifies the handling. But in general the light-oil refiners demand an oil of 20° or lighter, while the asphalt refiners can not use anything lighter than 15.5° Be. None of the crude oils of California are equal, for refining purposes, to the oils of Pennsylvania and Ohio, the percentage of the lighter products being on the average much smaller, but owing to local conditions (that is, to the high prices realized locally for petroleum products) many oils can be profitably refined here which could not be touched in less favored localities.

The following analyses were made at various times, and with different objects, so that they do not follow exactly the same lines. They indicate, however, in a general way, the commercial capabilities of various grades of California oils, and cover fairly well the entire range of qualities of oil found. The analyses marked "A" are of samples from wells with paying production, or from tank mixtures, while those marked "B" are from seepages or very small wells, and do not represent actual production:

B 1429. Bitterwater, San Benito County.

Well—Nonpareil Petroleum Co. Gravity, 42.7° Be.

	Gravity.	Per Cent.
Gasoline	68° Be.	10.0
Engine distillate	58	10.0
Engine distillate	53	10.0
Kerosene	44	35.0
Stove oil	35	15.0
Lubricants	19.7	19.3
Loss	---	0.7
		100.0

This is a greenish oil, containing traces of paraffin. The greasy residue contains traces of asphalt. Oil of similar character was found at various points through this county, but no paying production was developed.

B 480. San Mateo County.

Well. Gravity, 41.7° Be.

	Gravity.	Per Cent.
Gasoline	71° Be.	8.6
Benzine	63	12.9
Engine distillate	53	25.5
Kerosene	43	23.6
Stove oil	33	11.1
Lubricants	27	8.0
Black grease	--	7.0
Loss	--	3.3
		100.0

This is a greenish oil containing traces of paraffin, and seems to be allied more closely to the paraffin oils than most of the petroleums of California. It is not, however, a true paraffin oil. Several oils of higher gravity, but of the same general nature, have been found in this district.

B 442. Moody's Gulch, Santa Clara County.

Well—Golden Gate Petroleum Co. Gravity, 38.0° Be.

	Gravity.	Per Cent.
Engine distillate	56° Be.	25.0
Kerosene	44	38.1
Gas oil	32	33.9
Paraffin, solid	--	0.3
Coke	--	2.1
Loss	--	0.6
		100.0

This oil appears to be very closely allied to the true paraffin oils. There was at one time considerable production, the average being somewhat lighter than the sample above, but the output for the past two or three years has been practically nothing.

A 411. Coalinga, Fresno County.

Tank average—Oil City district. Gravity, 33.9° Be.

	Gravity.	Per Cent.	Gravity.	Per Cent.
Gasoline	75° Be.	0.9	--	---
Benzine	63	4.1	--	---
Engine distillate	53	6.4	50° Be.	25.7
Engine distillate	--	----	44	10.0
Kerosene	45	9.8	40	16.0
Kerosene	41	26.0	--	---
Middlings	--	----	32	24.3
Lubricants	--	----	22	18.0
Residue	Liquid	52.8	Pasty	6.0
		100.0		100.0

A 420. Coalinga, Fresno County.

Tank average—Oil City district. Gravity, 33.4° Be.

	Gravity.	Per Cent.
Gasoline	73° Be.	2.3
Engine distillate	57	3.2
Engine distillate	49	19.1
Kerosene	41	28.6
Stove oil	34	10.3
Gas oil	28	9.9
Fuel distillate	25	10.3
Lubricant	23	10.4
Residue	Pasty	4.7
Loss	--	1.2
		100.0

This green oil is, with the exception of the seepage oil from Colusa County, the farthest removed in its properties from the paraffin oils of any petroleum in the State. This sample is practically identical with the one preceding, and the three analyses show different methods of handling the same crude.

A 1431. Coalinga, Fresno County.

Tank average—"top sand oil." Gravity, 26.0° Be.

	Gravity.	Per Cent.
Gasoline	71° Be.	0.52
Benzine	60	7.96
Engine distillate	50	3.90
Kerosene	44	15.30
Stove oil	31	15.00
Fuel distillate	40	13.50
Lubricant	23	17.94
Lubricant	15	4.72
Asphalt	Grade "D"	17.00
Losses	--	4.36
		100.00

This is a black oil, and resembles the lighter oils of Fullerton and of Ventura County. Gravity for gravity, the southern oils give a somewhat better analysis than Coalinga oils, as a rule.

A 412. Ventura County.

Pipe-line average. Gravity, 28.0° Be.

	Gravity.	Per Cent.
Gasolines—total	63° Be.	10.4
Kerosene	42.5	28.0
Gas oil	28	16.1
Lubricant	23	20.3
Asphalt	--	23.7
Loss	--	1.5
		100.0

A 435. Ventura County.

Pipe-line average. Gravity, 25.2° Be.

	Gravity.	Per Cent.
Engine distillate	55° Be.	14.5
Kerosene	42	13.8
Stove oil	33	14.4
Fuel distillate	26	22.8
Lubricant	21	16.0
Asphalt	Soft, pasty	14.9
Loss	--	3.6
		100.0

Both these oils, like many other of the oils produced in this district, contain a trace of paraffin. These pipe-line averages include all but the very heaviest of the oils produced in Ventura County, and the output of oil heavier than 20° is inconsiderable.

A 1416. Coalinga, Fresno County.

Pipe-line average—"Ora Crude." Gravity, 20.6° Be.

	Gravity.	Per Cent.
Gasoline	81° Be.	0.15
Gasoline	74	0.46
Benzine	63	0.94
Engine distillate	54	2.34
Kerosene	42	11.47
Stove oil	33	1.86
Gas oil	31	32.24
Gas oil	28	3.43
Fuel distillate	26	5.06
Lubricant	22	17.83
Lubricant	17	4.84
Lubricant	15	1.06
Asphalt	Grade "B"	13.34
Losses	--	4.98
		100.00

A 492. Coalinga, Fresno County.

Pipe-line average—"Ora Crude." Gravity, 20.2° Be.

	Gravity.	Per Cent.
Engine distillate	54° Be.	4.34
Kerosene	41.3	7.09
Gas distillate	31	13.50
Fuel distillate	26	20.65
Lubricant	22	7.30
Lubricant	16.5	4.30
Lubricant	15.4	16.60
Asphalt	Grade "D"	22.70
Losses	--	3.08
		100.00

The above oils, which are practically identical, represent the average output of the eastern portion of the Coalinga field.

B 456. Colusa County.

Seepage oil. Gravity, 15.2° Be.

	Viscosity.	Gravity.	Per Cent.
Distillate	----	24.5° Be.	35.0
Lubricant	2.13	19.0	8.0
Lubricant	4.50	16.5	9.0
Lubricant	10.00	15.0	13.0
Lubricant	10.21—76° F.	11.0	13.0
Lubricant	42.02	Sp. Gr., 1.028	13.0
Asphaltic residue	----	Grade "F"	6.0
Loss	----	----	3.0
			100.0

This is a very remarkable oil, different from anything else in the State, aside from this immediate locality, and from other oils of which analyses have been published. It may be distilled freely, without steam or vacuum being used, and with little or no decomposition. The gravity of a distillate, from ordinary California crude, having the boiling points of the first fraction above, would be about 33° to 35°. This petroleum appears to consist almost entirely of aromatic hydrocarbons; the high specific gravity, 1.028, of the last fraction, is due to the nature of the hydrocarbons, not to asphalt or other foreign substances, as it is quite clear, and transparent in moderately thin layers.

Compare this analysis with that of the sample below, which was handled in almost the same manner.

A 422. Summerland, Santa Barbara County.

Tank average. Gravity, 14.0° Be.

	Gravity.	Per Cent.
Engine distillate	48° Be.	0.1
Kerosene	41	3.0
Stove oil	33	4.0
Gas oil	28	16.3
Fuel distillate	25	19.1
Lubricants	21.5	20.4
Asphalt	Grade "D"	37.1
		100.0

This sample is slightly heavier than the average oil of the Summerland district.

A 1432. Sunset, Kern County.

Well. Gravity, 14.1° Be.

	Gravity.	Per Cent.
Stove oil	33° Be.	12.7
Gas oil	28	20.1
Lubricant	22	5.7
Lubricant	20	12.7
Lubricant	16.6	16.2
Asphalt	Grade "C"	29.3
Losses	----	3.3
		100.0

This sample, which about represents average Sunset oil, was distilled with care to avoid decomposition. Compare this analysis with that of sample below, which was cracked as completely as is possible in simple distillation.

A 478. Sunset, Kern County.

Well. Gravity, 14.0° Be.

	Gravity.	Per Cent.	Per Cent
Distillate	56° Be.	----	4.6
Distillate	44	----	17.5
Distillate	33	20.4	----
Distillate	32	----	14.0
Distillate	30	49.6	----
Distillate	25.5	----	13.3
Residue	19.5	----	15.0
Asphalt	Grade "A"	19.0	19.0
Gas loss	----	11.0	----
Total losses	----	----	16.6
		100.0	100.0

The products of a distillation of this character are, in the higher gravities, unsuited for the uses to which corresponding distillates from the crude oil would be put, on account of their instability. The 56° distillate above is almost entirely, and the 44° distillate very largely, soluble in ordinary sulphuric acid.

A 1464. Sunset, Kern County.

Well. Gravity, 9.9° Be.

	Gravity.	Per Cent.
Stove oil	33° Be.	2.9
Gas oil	28	7.3
Lubricant	21	36.6
Asphalt	Grade "D"	51.4
Loss	--	1.8
		100.0

This oil is from the shallow sand in the southern portion of the field, and is about the heaviest oil produced in the State from actual wells; that is, from sands which are covered from contact with the air. Similar or heavier oils are often found at seepages.

A 1413. McKittrick, Kern County.

Well. Gravity, 18.0° Be.

	Gravity.	Per Cent.	Per Cent.
Kerosene	41.5° Be.	1.4	----
Kerosene	38	4.2	----
Stove oil	34	2.4	----
Stove oil	32	----	14.0
Gas oil	28	68.0	62.0
Asphalt	Grade "D"	22.5	22.5
Loss	--	1.5	1.5
		100.0	100.0

This is an average oil from the southern end of this district.

A 1411. McKittrick, Kern County.

Pipe-line average. Gravity, 15.2° Be.

	Gravity.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Kerosene	42.2° Be.	0.9	----	----	----
Kerosene	41.2	----	1.5	----	----
Kerosene	40.0	0.6	----	----	----
Kerosene	39.5	----	----	2.4	----
Kerosene	37.6	----	0.9	----	----
Stove oil	33.0	1.5	0.6	0.5	3.0
Fuel and lubricant	25.0	64.0	64.0	64.1	64.0
Asphalt	Grade "D"	32.0	32.0	32.0	32.0
Loss	----	1.0	1.0	1.0	1.0
		100.0	100.0	100.0	100.0

This is an average sample from the north center of the field, with the lighter portion separated and cut in different ways. It gives an idea of the variation in the yield of kerosene at different gravities.

A 1441. Kern River, Kern County.

Tank average. Gravity, 15.2° Be.

	Gravity.	Per Cent.
Kerosene	52.0° Be.	0.5
Stove oil	33.5	1.5
Gas oil	28.0	12.0
Lubricant	23.0	10.7
Lubricant	17.7	25.4
Lubricant	14.8	9.6
Asphalt	Grade "E"	38.7
Loss	---	1.6
		100.0

The sample above is an average sample of oil from this field, and was run in the manner usual when making asphalt and distillate, the distillate being fractionated from the crude still.

A 1442. Kern River, Kern County.

Tank average. Gravity, 15.2° Be.

	Gravity.	Viscosity.	Flash. Point.	Burning. Point.	Per Cent.
Distillate	39.6° Be.	---	---	---	2.6
Stove oil	32.8	---	---	---	3.4
Gas oil	28.0	---	---	---	6.7
Lubricant	24.2	2.63	246° F.	281° F.	5.9
Lubricant	22.5	3.10	278	316	3.3
Lubricant	21.3	5.61	308	342	2.0
Lubricant	19.7	10.52	320	364	5.1
Lubricant	18.4	19.60	337	396	5.3
Lubricant	17.5	41.96	333	414	4.6
Lubricant	14.6	150.00	---	---	19.2
Asphalt	Grade "E"	---	---	---	38.7
Losses	---	---	---	---	3.2
					100.0

This sample is identical with the one above, but was run with special care to avoid decomposition, and the distillate then refractionated. The lubricants above are distillates, with the exception of the last. The gravity of the bulk distillate, before rerunning, was 20.5° Be.

A 1487. Kern River, Kern County.

Tank average. Gravity, 15.5° Be.

	Gravity.	Viscosity.	Flash Point.	Burning Point.	Run 1.	Run 2.	Run 3.	Run 4.	Run 5.
Kerosene	42.0°	----	110° F.	122° F.	0.5%	0.5%	0.5%	0.5%	0.5%
Paraffin oil	24.0	2.52	257	286	52.0	----	----	----	----
Distillate	38.6	----	----	----	12.3	----	----	----	----
Spindle oil	22.0	5.02	298	328	----	39.0	----	----	----
Stove oil	34.1	----	----	----	----	28.0	----	----	----
Neutral oil	20.4	11.20	320	372	----	----	28.6	----	----
Gas oil	31.7	----	----	----	----	----	35.7	----	----
Machine oil	18.6	21.48	358	412	----	----	----	18.2	----
Gas oil	30.2	----	----	----	----	----	----	46.3	----
Engine oil	17.1	58.00	408	452	----	----	----	----	8.8
Gas oil	32.0	----	----	----	----	----	----	----	39.0
Neutral oil	21.5	----	----	----	----	----	----	----	16.6
Asphalt	Grade "D"		----	----	33.0	33.0	33.0	33.0	33.0
Losses	----	----	----	----	2.2	1.5	2.2	2.0	2.1
					100.0	100.0	100.0	100.0	100.0

This sample is very similar to the one above, but the lubricants were prepared by reducing the bulk distillate, in steam still. The comparison of gravities, viscosities, and flash points, between this analysis and the preceding, will show plainly the much greater suitability of this method of working, particularly as the bulk distillate was run without care to avoid cracking, had the gravity 27.0°, and was therefore a much less satisfactory material to work with.

It is obviously impossible to print any great number of commercial analyses in this connection, because of the considerable labor involved in the preparation of each, and of the fact that most of the analyses on file were made for private parties, and are not available for this purpose. But a simple distillation may, when interpreted with care, throw a certain amount of light on the nature of a crude oil, and on its probable value for refining purposes.

The figures in the accompanying table (No. 25) were made by the following method: A small sample, from 100 c.c. to 250 c.c., was distilled in a glass flask with side neck, the bulb of a thermometer being placed just below outlet. Fractions were collected, (*a*) from commencement of distillation to temperature of 150° C., (*b*) from 150° to 270°. These fractions were then calculated to gasolines and naphthas, and to kerosene, the gasolines being read together. The rules by which these calculations are made were deduced from results of experiment, and are not worth detailing; it should be noted that the figures thus obtained *are estimates, and do not pretend to be accurate.* The residue from this distillation is transferred to an iron retort, very low and wide, and further distilled until the asphalt attains the desired consistency, usually a "D" grade. By making the retort of metal, and very low in proportion to its width, decomposition of the lubricating oils is almost entirely avoided. The distillate from the iron retort is placed in another small retort, and distilled under a vacuum of twenty-three inches, up to a temperature of 270° C., the thermometer bulb being in the vapor. The distillate from this rectification is classed as "middlings," which would include stove, gas, and fuel distillates. The gravity stated for middlings is the gravity of *this distillate*, but the quantity is found by adding to the percentage represented by this distillate a calculated percentage of residue from the 150°–270° distillate. The residue from the last distillation is classed as lubricating oil, and the gravity stated.

Where only a small sample is available or where the amount of labor to be expended on the analysis is limited, this method offers a satisfactory means of estimating the value of an oil. The results obtained in this way do not, of course, compare in accuracy with the results of a careful analysis of a large sample, as the laboratory analysis of a sample of several gallons should be almost if not quite as reliable as a refinery test.

A number of the samples included in Table 25 were tested some time since, and on these the middlings and lubricants were not separated. A number of these tests were made in the writer's laboratory by Mr. Wayne Colver, several also by Mr. E. N. Moor. In this connection, see also "Analyses of California Petroleum," by Mr. H. N. Cooper, at end of this bulletin.

Methods of Refining.—The refining methods in vogue in California, while following in general along well-settled lines, vary considerably in details. Different crude oils require somewhat different treatment, the demands of the market vary somewhat at different points, while individual opinion differs widely as to the most suitable treatment in any given case. For these reasons, any description of refining processes must be of the most general nature, and the following remarks are intended merely to show, to those entirely unfamiliar with the subject, the outlines of the methods employed.

Petroleum refining, in general, consists in a fractional distillation of the crude oil, followed by the action of chemicals and water on the crude fractions, and generally, though not always, of a second distillation following the chemical treatment.

The nature of a fractional distillation is too well known to need elaboration.[1] The essential principle is, that on heating a mixture of liquids having different boiling points, the most volatile will boil first, then the substance having the next higher boiling point, and so on. But the lowest boiling liquid will not distill over in a pure state, but will carry over with it portions of the heavier substances, so that the separation is but partial, and to effect complete separation the process must be many times repeated.

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[1] Any good organic chemistry will explain the scientific principles on which fractional distillation is based.

As crude petroleum is a mixture of an indefinite, and very large, number of substances having different boiling points, and as each of these liquids, as it distills, carries over with it more or less of the other elements, the boiling point of the mixture will not rise by jumps, but will increase steadily as distillation progresses, the change from one substance to the next being generally quite imperceptible. And as it is a general rule that the higher the boiling point of a substance the lower the gravity (when considering any one petroleum), the gravity of the distillate will lower gradually and evenly as the distillation progresses. For these reasons, the commercial fractions made from crude petroleum are not definite substances, but are themselves very complicated mixtures, and the dividing line between any two substances is not a natural and inevitable, but an arbitrary one, fixed by experience and by the qualities desired for the products. In general, the change from one cut to another is made when the distillate flowing from the condenser has reached a certain set gravity reading.

Stills.—The crude oil is pumped from the storage tanks, usually by means of "low-service" duplex piston pumps, into the stills. These are sheet steel cylinders, constructed of steel of low tensile strength, which withstands the action of heat better than the harder grades. The longitudinal seams of these shells are double riveted, the roundabout seams single riveted, the rivets being pitched a little wider than is customary in boiler work. Where possible the bottom of the still is constructed of one sheet, thus avoiding rivet heads over the fire.

Oil stills are plain cylinders, exactly resembling, to use a homely parallel, an empty baking-powder can laid on its side. There are no flues or tubes, and in general no bracing, but the shell is provided with a small dome, a manhole in the top, another in one head, a "test column" on one head, connected into the body of still at top and bottom, and equipped with a row of pet-cocks, the latter serving as gauges to determine the level of the liquid in the still. Flanges are also provided for inlet, outlet, vapor, and steam pipes.

The stills are set in brickwork, in various ways. In one form of setting, the still is supported on lugs resting on the side walls, the outer face of brickwork at front and rear being carried up flush with the heads. This setting is economical of brickwork, and protects the end seams from the fire, but considerably reduces the heating surface of the shell, as a length equal to the combined thickness of front and rear walls is covered. In another form of setting, eyes are riveted to top of still, hooks engaging these eyes swing from "I" beams, the latter resting on brickwork or metal columns outside of setting, or on columns carried up from side walls. The front and rear walls are carried up clear of the shell, to about the center line. This form of setting has the great advantage that expansion and contraction of the shell do not rupture the setting, the still swinging quite free, and that the entire lower surface of the shell is available heating surface; but the cost is considerable, and the end seams are exposed to the fire. Other forms of setting are modifications or combinations of these two types. Whatever form of setting is used, all exposed surfaces are carefully covered over with some non-conductor of heat, to avoid loss through radiation, and decomposition of the distillate. The firebox is without grates, of simple construction, oil burners being always used, and the fire gases pass down the length of the still and directly into a flue at the rear end.

Condensers.—The vapors from the boiling oil pass through a pipe, called the "vapor pipe," into the condenser. Condensers are of various forms, but almost always constructed of wrought pipe. On small stills a simple coil, decreasing in size downward, will answer; for larger stills, parallel coils, run into a header at inlet and outlet ends, or banks of pipes carried into headers on each bank, are more commonly used, the aim of these arrangements being to increase the discharge area of the condenser and thus diminish the back pressure on the still. It is evident that if thirty feet of pipe, for instance, is connected up in three lengths of ten feet each, from one vapor pipe, the discharge area will be three times what it would be if the thirty feet were coupled onto the vapor pipe in a continuous length, while the condensing surface will remain the same. Whatever the form of the condensing coils, they are immersed in a water box, and kept covered with a changing supply of cold water, by which the vapors are cooled and reduced to a liquid form.

From the condensers, the distillates, now reduced to a liquid, pass into a small building known as "tail-house" or "receiving-house." Here the pipes are connected into iron boxes, provided with an outlet below for the stream of distillate, and above for the gas always accompanying the oil. The stream flowing through this box may be seen through small glass windows, and the size and color of the stream thus examined without exposing it to the air. From the sight-boxes the distillate is passed through a series of valves, by which it may be directed to the proper tank. The distillate finally reaches its place in the cut-tank, where it is stored for further treatment.

Regulation of Distillation.—The distillation is regulated by the gravity of the distillate usually, though sometimes by the temperature of the still. Practically all the oils of the Pacific Coast leave a residue of asphalt, and the distillation is finished when this asphalt, which remains behind in the still, reaches the proper hardness. It is tested from time to time by withdrawing small quantities through a test-cock.

The distillation being finished, the fire is shut off, and the still and contents allowed to cool a short time, and the asphalt then drawn into the coolers.

Coolers.—These are closed iron or steel tanks or boxes, of any desired shape, either cylindrical or rectangular. The object of the cooler is to enable the still to be emptied while the asphalt is still very hot. Asphalt at a high temperature can not be drawn into an open tank, because of the suffocating vapors and the danger of fire, but by having the coolers closed except for a small vent, the asphalt may be drawn from the still at any heat desired. It remains in the coolers until sufficiently reduced in temperature to enable it to be drawn into barrels.

Steam is usually passed into the still during the progress of distillation, the object being to reduce the heat necessary and to prevent decomposition of the distillate. The heavier vapors of petroleum are very dense, and correspondingly heavy, and do not readily ascend through the vapor pipe, but have a tendency to lie in the still and to decompose from contact with the heated sides of the shell. The vapor of water is very light, and by injecting dry steam into the still, the oil vapors are carried out of the still mechanically, and the boiling temperature considerably lowered. Another function of the steam is to promote circulation of the oil, the steam pipes being laid along the bottom, with the perforations pointed in such direction as to cause the oil to circulate up the sides and down in the center, or otherwise as desired. This scours the bottom sheets, and prevents the oil from coking fast to the shell. The steam is sometimes superheated by a coil in the firebox, but more often by passing it through a blank coil within the still itself. By the latter method the steam is always heated to about the temperature of the oil, and burning of oil by overheating of steam prevented. Steam is usually started as soon as the water accompanying the oil has distilled off, and kept on to the end of the run, it being considered desirable to reduce cracking of the lighter distillates as far as possible. California oils are, as a rule, rather tender, and have to be distilled with care. For reasons mentioned in the following chapter, they are never cracked intentionally, to increase yield of kerosene.

Treatment.—From the cut tanks, such oils as require chemical treatment are pumped to the agitators. These are upright cylinders, with conical bottoms, generally though not always lined with sheet lead, and provided with air blast and with outlets for the spent chemicals and the treated oils. The chemicals generally used are the strongest sulphuric acid, and caustic soda or other alkalies. The object of the sulphuric acid is to oxidize the unstable elements in the oil and to take them into solution. The acid is thoroughly mixed with the oil by means of a blast of air, and then allowed to settle, and drawn off. The spent acid is sometimes made use of, but generally allowed to run to waste. After the acid, which is now thick and black, has completely settled, the oil is usually washed with water, and then with an alkaline solution, the object of the latter being to dissolve and carry away certain acid impurities not destroyed by the sulphuric acid, and to neutralize any traces of the latter remaining in the oil. After the alkali has settled and been withdrawn, the oil is repeatedly washed with water, until all traces of alkali are eliminated, then drawn off, and allowed to settle until perfectly clear.

Chemical treatment, while simple in outline, is very complicated, and often very haphazard, in practice, and varies immensely with different products, as well as with different qualities of crude oil. In general, however, no other chemicals than those mentioned are used, and these in small quantity, from a fraction of a per cent up to two or three per cent, by bulk, of acid, and a very small percentage of highly dilute alkali. California oils are not, as a rule, very refractory to treatment, but require careful manipulation.

Redistillation.—Many products demand a second distillation after the treatment. Sometimes the entire body of the oil is redistilled, with the object of a closer fractionation; more often the oil is merely heated, and the lighter elements blown off by means of steam, this process being known as "reduction," and the still as a "steam still." Sometimes the oil thus reduced is again treated, more often it is ready for the market directly from the still.

Manipulation of Products.—The **Gasolines** are generally run into a stock, cut from the commencement of distillation down to a point varying with the crude, and with the grade of kerosene desired. The cut will usually be made when the gravity at tail-box is somewhere about 52°. This stock, the gravity of which will vary enormously, is given a light treatment with acid and soda, cleared, and redistilled by means of indirect steam. The distillates from the gasoline still will usually be marketable without further treatment, although if the crude is very bad the engine distillate, which comes over last, may require a very light treatment to bring up its color. There should be practically no residue from this distillation.

The **Kerosene** is cut from the end of gasoline stock, that is, about 52°, down to 39°, 38°, 37°, or even 36°, according to the crude, and to the grade of kerosene desired. The raw cut is carefully treated and cleared, and is then passed back to the kerosene still. Some refineries redistill the kerosene, leaving a slight residue which is practically waste, and taking off a small initial cut which goes to engine distillate; others prefer to simply reduce the kerosene by distilling off a small quantity with a large supply of steam, the kerosene remaining as a residue. In either case, the kerosene will require a second treatment with acid to bring its color up to standard.

Stove Oil is generally a cut from the crude still, following the kerosene. If a red oil is to be made, a treatment with alkali alone (a strong solution) will answer; but if pale grades are to be made, treatment with acid and alkali is necessary. If the crude still is properly regulated, a satisfactory flash point will be had without further precautions.

Middlings.—Between the stove oil and the lubricants there is almost always a portion of the distillate which can not be made of use except as fuel, unless a market for gas oil is at hand. This distillate runs 25° to 27° gravity, and yields practically nothing of value to redistillation, and is therefore sold or used in the crude state.

Lubricating Oils are made from the last distillates, and in a great variety of ways. For the lighter neutrals, a distillate from the crude still is sometimes treated, and sold without further distillation or reduction. For heavier oils, either a portion or the entire bulk of the heavy distillate is reduced in a steam still to the gravity or viscosity desired. This distillate may or may not be treated before reduction, but is always treated either before or after passing through the still, sometimes, where high grade is desired, both before and after. The lubricants from California crude will seldom stand actual redistillation, decomposing badly even where the greatest care is used. The distillates from the lubricating steam still are light products of decomposition of the heavier oils, and of very little value. As our local oils are practically free from paraffin, lubricants made here do not require cooling or pressing, but have a very low cold test naturally. Filtration (through bone-coal) is not practiced here, unless at one refinery.

Distillation for Asphalt.—Large quantities of the heavier oils are now being distilled for the production of asphalt. It will be noted from the tables immediately above that the oils heavier than 16° Be. contain little if any of the lighter products, gasoline being entirely absent, and kerosene present only in minute quantity. Where oils of this nature are distilled, the asphalt is the product of value, the distillate having practically the same value as crude oil.

Many attempts have been made to convert these heavy distillates into lighter products, either by manipulation of the original distillation, or by subsequent treatment, but so far none of these processes have met with commercial success. The reason is probably not far to seek. These heavy oils are subject, like any others, to decomposition, but owing to their chemical constitution, the light products of decomposition have no commercial value, being very foul, difficult to purify, and not retaining their color when purified. Further, if the decomposition is effected in the crude still, the quality of the asphalt is seriously injured; while if effected in a second distillation, the cost is prohibitive, as only a small portion of the oil can be cracked down in a single distillation, and the gas loss is very high. Certain reasons why this cracking of heavy oils into light will probably never be possible with California oils, are given in the following chapter; for the present, it is sufficient to say that no such process has yet been made to succeed, and the practice in the heavy oil refineries is to take every precaution against cracking.

The stills used in these plants are of comparatively large size, up to six hundred barrels each, though averaging perhaps half that capacity. They are strongly constructed, heavily set, and carefully covered in. Large condenser area and surface are also provided, to reduce pressure on the still to a minimum. The coolers are of large size, generally so constructed as to hold several runs, the asphalt being let in on top and drawn off below at the same time.

The distillates from these oils range from 24°, where a very large steam supply is given the stills, to 27°, where less steam is used; the quality of the asphalt is probably somewhat improved by the use of a plentiful steam supply.

Oil Asphalt.—The asphalt left as a residue in the distillation of California crude oil is a very peculiar and highly valuable product, and merits an extended description.

According to the amount of distillate removed from the crude oil, oil asphalt is a thickly fluid or solid substance. The liquid grades are usually somewhat stiffer than molasses, at ordinary temperatures, becoming completely liquid at moderate heat. The color by reflected light is lustrous black, with sometimes a faint brownish or purplish tinge, but by transmitted light, in very thin layers, is deep ruby red. There is little or no odor, usually a slight salty taste. The solid grades range from a consistency which may be worked between the fingers to one of great hardness and friability. These grades have a very high luster, and are jet black. The medium grades are extremely ductile, and when of good quality are capable of being drawn into threads of microscopic fineness, many feet in length. These medium qualities are stiffly viscous; that is, even when hard enough to be shivered by a sharp blow, they are deformed by steady pressure, this quality sometimes being so noticeable that asphalts which might be walked over without being marked will soon bury any small object left lying on the surface.

Table 26, following, shows the principal physical characteristics of the various grades of oil asphalt. These are considered average samples, but there is some difference in the output of different plants.

TABLE 26. PHYSICAL PROPERTIES OF CALIFORNIA OIL ASPHALTS.

Grade.	Specific Gravity.[1]	Penetration 77° F.	Melting Point.[2]	Flash Point.	Burning Point.	Consistency at 60° F.
L	0.985	------------	75° C.	175° C.	205° C.	Thick liquid.
G	1.010	------------	85	180	215	Gummy, semi-solid.
E	1.045	27.7	130	190	245	Somewhat plastic.
D	1.080	18.6	135	200	270	Firm, tenacious.
C	1.085	8.9	155	220	270	Rather brittle.
B	1.100	4.1	180	250	300	Very brittle.

[1] The specific gravity varies somewhat, on any one grade, with differences in the crude oil.

[2] No definite melting point. At temperature stated the asphalt is completely and rather thinly liquid.

Oil asphalts are acted on in the usual manner by solvents for asphaltic bitumens. They give up a small amount of soluble matter to absolute alcohol, are partly soluble in light petroleum gasolines, completely but not permanently soluble in heavy California naphthas, completely and permanently soluble in the heavy oils from California petroleum, but less readily and completely in the heavy oils from paraffin-bearing petroleums. They are completely soluble in benzole and heavier coal-tar oils, in carbon bisulphid, chloroform, and carbon tetrachlorid, and partially soluble in ether and acetone. The usual analysis, by solution in turn in gasoline or ether, and carbon bisulphid or chloroform (*i. e.*, the separation into "petrolene" and "asphaltene"), is not very informing, as the results are more or less influenced by the conditions under which the estimation is made, and seem to have very little relation to the working value of the bitumen. Neither petrolene nor asphaltene, as thus separated, are simple substances, as may readily be proven by the fact that asphalt of ordinary hardness (a "C" or "D" grade) will give up soluble matter in turn to alcohol, light petroleum gasoline, sulphuric ether, benzole, turpentine, and chloroform, all the substances thus isolated having different physical properties. The actual chemical constitution of these asphalts may be said to be entirely unknown. They are known to contain a large percentage of carbon, and a small percentage of hydrogen; sulphur is nearly always present in slight amount, but appears to be incidental, as is oxygen, and occasional traces of nitrogen. It is very likely that these bodies consist of hydrocarbons with a very high carbon percentage. They are hardened by the addition of sulphur, at moderately high temperatures, hydrogen being given off as hydrogen sulphid, and this treatment carried to its limit will completely remove the hydrogen, leaving a residue of coke. Oxygen has the same effect, eliminating hydrogen as water, but atmospheric oxygen at normal temperatures, acting much more slowly, seems in some cases to be actually absorbed, as there is sometimes an increase of weight. The asphalts formed by spontaneous oxidation of crude oil are much tougher and more ductile than those due to forced oxidation, and there appears to be a constitutional difference. Forced oxidation has a tendency to decompose the asphalt itself, precipitating free carbon, even before any great hardness is reached, and for this reason, though it is possible to convert almost the entire weight of the heavier crude oils into asphalt, by the application of oxygen or sulphur, the process is of little commercial value.

The asphalt produced from crude oil is only in part present in the oil before being distilled, being largely formed during distillation. This may readily be shown by washing crude oil with excess of sulphuric acid, by which means the asphalt may be entirely removed. An oil which would produce 35% of asphalt by distillation under ordinary conditions, or 45% to 50% by evaporation in contact with the air, at a temperature below its boiling point, may be washed quite free from any black tinge with a loss of from 10% to 15% of its bulk. The same thing may be inferred from the percentage of precipitable asphaltene in the crude oil. Many oils yielding the above percentage (35%) of asphalt on distillation contain less than 2% of asphaltene, which at the ordinary ratio of one part asphaltene to four parts petrolene (about the usual analysis of "D" asphalt) would represent 10% or less of actual asphalt in the crude oil. The asphalt appears to be produced by partial decomposition of the heavier portions of the crude, and the percentage yield is to some extent dependent on the conditions under which distillation is carried out. Forced distillation at high temperatures gives a larger yield of asphalt, but of lower grade than that produced by slow distillation with a large steam supply. The critical temperature for the production of asphalt seems to lie about 600° F. Below this temperature the action of the still is merely one of concentration; that is, a sample of the residue drawn from the still, and blended with a proportion of distillate equal to the amount distilled off, will have the same percentage of asphalt as the original crude. But above this temperature the crude commences to be actually converted into asphalt, and a sample withdrawn from the still and blended with the proper proportion of distillate will contain more asphalt than the original crude oil, the percentage of excess increasing with the length of time to which the oil has been exposed to heat in the still. However, where steam is used, the temperature need be raised but little above 600° F., it being quite possible to reduce the oil to any grade of asphalt desired without passing 600° F.; distillation in this manner is very slow, and a large amount of steam is required. The distillates show by their gravity that very much less decomposition has taken place than where higher temperatures are maintained, the gravity of the entire bulk distillate from 15° crude running about 20° Be. where the still was kept at 650° F., while if run at 750° F., about the usual temperature, the gravity would run somewhere about 26° Be.

Oil asphalts are very little affected by water, either pure or mineralized, or by solutions of an alkaline nature. Acids without oxidizing power attack them but little, but the oxidizing acids and chlorin water destroy them rapidly. Their immunity from decay in contact with water particularly fits them for street paving, and for use in other situations where natural asphalts are decomposed. In contact with air they are reasonably durable, though somewhat less so than the natural asphalts, gradually losing their ductility, and becoming friable, and finally oxidizing to a brown powder; this action is very slow.

The greatest advantage possessed by oil asphalts is their freedom from impurity. Where properly prepared, as almost the entire output now is, they contain but a trace of mineral matter, and generally less than one per cent of "organic matter not bitumen." The latter is misnamed in this case, as the insoluble combustible matter in oil asphalt is not organic in any sense, but consists of free carbon in finely pulverized form, produced by slight local overheating of the stills during distillation. This carbon, being entirely neutral and stable, is no detriment to the quality of the asphalt, and should be carefully distinguished from the organic matter in natural asphalts, which is actually organic, and subject to decay. The mineral matter consists of traces of sand and of microscopic silicious skeletons of marine diatoms. Clay is very seldom found in sufficient quantity to be distinguished from the silica.

Owing to their freedom from insoluble matter, these asphalts are very suitable for the preparation of paints and varnishes, though not of goods of the highest grade. The freedom from infusible matter is of considerable importance, as it enables them to be melted and kept melted without the coking or sedimenting of kettles, and as they melt at a comparatively low temperature, and are very fluid when melted, they are handled and applied with great ease. For operations involving coating, dipping, painting, or saturating, they are unexcelled, as they adhere firmly to paper, wood, and all metals, and form a close, coherent, and brilliant coating. They are rather more affected by changes of temperature than are natural asphalts.

Liquid Asphalts are used largely as fluxes for hard natural asphalts, and for this purpose are unequaled. They are actual solvents of asphalts of all kinds, and the mixture once effected is absolutely permanent, there being no danger of separation, even if the mixture is kept melted for a long time. It is evident enough that a substance which dissolves asphalt is a more rational flux than a substance which, like the residuum of paraffin petroleums, has to be mixed and kept mixed with the asphalt by a strong air blast or other means of agitation.

Paving.—Oil asphalts have, within the past few years, been extensively used for paving, and while the earliest experiments were not altogether successful, more extended experience seems to have proven their entire suitability to this use. The grades commonly used for this purpose are soft "D," or "E," ranging in penetration from 20 to 40 (Dow scale). These grades are solid at ordinary temperatures, but may be marked by the pressure of the fingers; at this hardness they are free from crumbling at low temperatures. As these asphalts are practically free from any foreign substance, it is usually considered essential to include in the paving mixture a certain amount, say ten per cent or so, of finely powdered mineral matter, to fill the voids between the finer sand grains. The nature of this mineral matter does not seem to be of any particular importance, so long as it is insoluble, as its action in the mixture is purely a physical one, and there is no combination except that of cohesion between the mineral matter and the asphalt. Some of the recorded failures of oil asphalt for paving were undoubtedly due to the omission of this fine mineral matter. It is a point sometimes overlooked, in proportioning a paving mixture, that an asphalt which will not crumble at very low temperatures, will be permanently plastic at normal temperatures, and that if voids are left between the sand grains, the latter will roll on each other, and the pavement be rapidly pressed out of shape. The object of the finely pulverized mineral matter is simply to wedge the grains of sand, and thus to prevent this rolling action, and where the sand is clean and the asphalt free from any insoluble matter, as is California oil asphalt, this detail is all important.

Some of the best pavements in the city of San Francisco and of Los Angeles have been laid with oil asphalt, and numerous other satisfactory pavements of this nature are to be found in various parts of the State. Several of these pavements have been laid eight years or longer, and are still in the best of condition, having been practically free from the necessity of repairs in the meantime.

The stone-block pavements in San Francisco are grouted with cement, but are laid on a foundation composed of broken stone with oil asphalt, as are also the later sheet asphalt pavements. The binder coat thus formed is elastic, durable, and cheap, readily cut and repaired. It is much more stable than a sand cushion, while the asphalt renders the pavement less noisy than where the wearing surface is laid directly over cement.

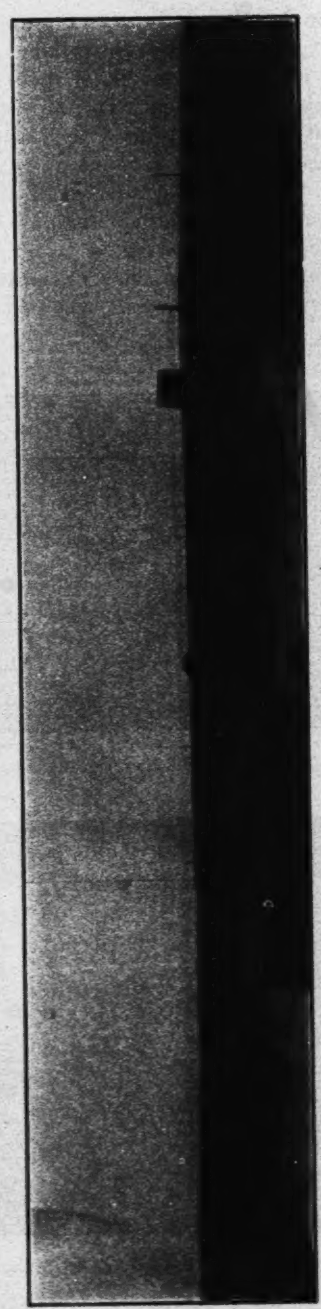
The Refining Industry of California covers the operations of some thirty-two firms, with thirty-four refining plants. The accompanying table (No. 27) gives a list of these plants, with remarks as to capacity and class of products. In regard to the latter, it may be stated that "light products" is used to designate the articles ranging from the lightest gasoline to kerosene, and that "distillate" as here used does not refer to the high-grade article of that name used in explosion engines, but to the crude distillate used principally for fuel.

The asphalt market is largely in the hands of the "California Asphaltum Sales Agency," a mutual association of a number of the larger refiners of asphalt, who pool their sales and maintain a uniform price.

No. 38. Machine for Making Asphalt Paper Pipe. A. P. P. Co., Los Angeles.

No. 39. California Oil Asphalt—Heading the Barrels.

No. 40. Refinery—Pacific Coast Oil Company, Point Richmond, Cal.



No. 41. Refinery—Sunset Oil and Refining Company, Obispo, Cal.

No. 42. Refinery—Asphaltum and Oil Refining Company, Los Angeles.

No. 43. Refinery—California Liquid Asphalt Company, Summerland, Cal.

No. 44. Refinery—Clark Refined Oil Company, Kern River Oil Field.

No. 45. Refinery—Columbian Oil, Asphalt and Refining Company, Carpinteria, Cal.

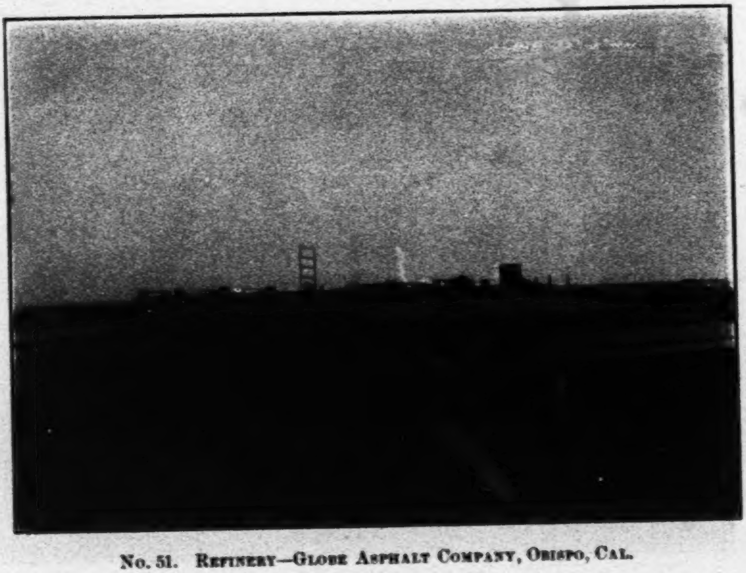
No. 46. Refinery—Coombs Refining Company, Los Angeles.

No. 47. Refinery—Densmore-Stabler Refining Company, Los Angeles.

No. 48. Refinery—Capitol Refining Co., Stockyards, Cal.

No. 49. Refinery—Eastern Cons. Oil and Refining Co., Kern River Oil Field.

No. 50. Refinery—Globe Asphalt Company, Obispo, Cal.



No. 51. Refinery—Globe Asphalt Company, Obispo, Cal.

No. 52. Refinery—Hercules Oil Refining Company, Los Angeles.

No. 53. Refinery—King Refining Company, Kern River Oil Field.

No. 54. Refinery—Navajo Oil and Refining Co., Sunset, Kern County, Cal.

No. 55. New Franklin Oil and Refining Company, Los Angeles.

No. 56. Pacific Oil Refinery, Los Angeles.

ALCATRAZ
ASPHALT

No. 57. Refinery—Pacific Oil Transportation Company, Gaviota, Cal.

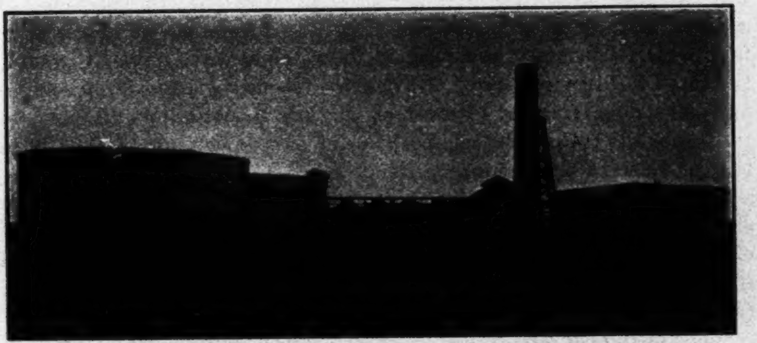
No. 58. Refinery—Pacific Refining Company, Bakersfield.

No. 59. Refinery—Puente Oil Company, Chino, Cal.

No. 60. Refinery—Southern Refining Company, Los Angeles.

No. 61. Refinery—Southwestern Oil Refining Co., Kern River Oil Field.

No. 62. Refinery—Union Cons. Oil and Refining Company, Los Angeles.



No. 63. Refinery—Union Oil Company of California, Kern River Oil Field.

No. 64. Refinery—Volcan Oil and Refining Company, Kern River Oil Field.

CHAPTER 16.

CHEMISTRY OF CALIFORNIA PETROLEUM.

The chemistry of the petroleums produced in California is involved in considerable obscurity. Investigations of this character are so difficult and tedious, and the rewards so doubtful, in a practical way, that very little research along these lines has been attempted, and it is probable that no single sample of Pacific Coast petroleum has ever been resolved into its proximate constituents. But though detailed information is lacking, some facts of a general nature may be brought forward, and these points, scattering as they may be, will yet throw some light on the ultimate nature of the oils with which we have to deal.

Hydrocarbons.—It is very evident, from a good many considerations, that the hydrocarbons making up the body of California petroleum are radically different from those of the oils of the Eastern States. The low flash point and boiling point in relation to the specific gravity, the practical or entire absence of solid paraffins, the presence of asphalt in most of our oils, and its ready formation on heating oils from which it has been removed, or in which it was originally absent, the rapid fall in viscosity of the heavier oils with rising temperature, and the strong tendency of most of our oils to oxidation, all point to the probability that the composition of our oil is quite distinct from that of Eastern petroleum.

The petroleum of the Eastern States is known to consist almost entirely of paraffins in the lighter members, and of paraffins and olefins in the heavier portions. The petroleums of the Caucasus are stated to consist principally of the naphthene group, while some German petroleums are stated to contain notable proportions of hydrocarbons of the benzene series. Various observers[1] have found in California petroleum all of these constituents, and as a discussion of this very abstract question would be out of place here, reference is given to the original papers for justification of the statement that most California petroleums, or rather their distillation products, contain hydrocarbons of all the following series: paraffins, olefins, probably acetylenes and other highly unsaturated compounds, naphthenes (cycloparaffins), and aromatic (benzene) compounds.

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[1] Consult—
A. S. Cooper. Mining and Scientific Press, 82-123; Bulletin 16, State Mining Bureau.
Felix Lengfeld and Edmund O'Neill. Amer. Chem. Jour., 15-19.
Charles F. Mabery. Am. Chem. Jour., 19-796; Am. Chem. Jour., 25-253; Jour. Soc. Chem. Ind., 19-502.
S. F. Peckham. Am. Jour. Science., 3-48-250; Science, 23-74.
Clinton Richardson. Jour. Soc. Chem. Ind., 19-123.
Frederick Salathè. 13th Report of the State Mineralogist.

A very few of the local oils give a light distillate which appears, from its specific gravity and other physical properties, to consist largely of paraffins, but the major part of our oils give a light distillate which is much heavier than a mixture of paraffins of corresponding boiling point could be. By acting on these gasolines and kerosenes, the olefins may be removed, and as sulphuric acid used in excess absorbs but a very small proportion, it may be assumed that the olefins are not present in large quantity. After rigorous treatment with sulphuric acid, a varying but large proportion of the oil is acted on by nitric acid, forming a stable nitro-compound, and leaving a residue which can not be further affected. This residue is very much lighter than the original oil, and from its resistance to all reagents probably consists of pure paraffins. The portion removed by nitric acid may be either benzenes or naphthenes, or both. It is probable that the latter is the case, though the percentage of benzenes must usually be quite small, as the gravity of benzene proper (C_6H_6) is about 28° Be., and the boiling point 80°, while the gravity of local petroleum distillate boiling at this temperature is well above 70° Be. It is apparent that if the distillate consisted of benzene and paraffins alone, the gravity of benzene being 0.885, and of a mixture of hexane and heptane, boiling at 80°, being 0.766, the greatest possible proportion of benzene in a mixture of 0.700 (70°) gravity would be 16%.

There is no reason for supposing that the small proportion (if any) of aromatic compounds in California petroleum will ever repay the cost of separation, particularly as these substances are now very low in price, and readily obtainable otherwise. But the presence of the naphthenes very seriously affects the quality of some of the products of our petroleum, notably the kerosenes.

It has been pretty well proven by experience that a kerosene, to be rated first quality, must consist practically of paraffins, as these bodies are the most stable of the hydrocarbons, and contain the largest proportion of hydrogen. It is necessary that the hydrocarbons should be stable, that is, not subject to oxidation or to spontaneous decomposition, as otherwise the kerosene will, on standing, lose its white color, acquire a foul odor, and be otherwise deteriorated. Also, the higher the percentage of hydrogen in the kerosene, the smaller will be the proportion of air required for complete combustion, and the less the tendency to smoking when burned. The olefins, which come next to the paraffins, contain more carbon and less hydrogen, and are more unstable. Consequently, kerosene, like the oils produced by cracking paraffin petroleums, which consist largely of olefins, is of distinctly inferior quality. The naphthenes contain a still larger percentage of carbon and a smaller percentage of hydrogen than the olefins, but are more stable, consequently a kerosene constituted (like that produced locally) largely of these bodies, will have more tendency to burn with a yellow or smoky flame than either of the foregoing, but will be somewhat more stable, when purified, than a kerosene produced by cracking.

The cracking of paraffins produces lighter paraffins and olefins, the cracking of olefins produces olefins and also acetylenes or other highly unsaturated and very unstable bodies, while neither the naphthenes nor the benzenes are susceptible to cracking, under ordinary conditions. For this reason, the attempt to improve matters with our oils by cracking has merely exaggerated the evil, destroying the best instead of the worst elements of the oil, and producing large quantities of very unstable bodies which have to be completely removed by the chemical treatment. It seems altogether probable that the bad qualities found in California kerosene are inherent in the nature of the oil, and can not be removed by any possible treatment or manipulation.

The distillates heavier than kerosene appear to have the same general constitution, though the olefins are more in evidence. The rough separation, by means of acid solvents, of a number of samples of heavy distillate from Kern River oil (gravity 25° to 27° Be.) indicates the following approximate constitution:

Olefins	30% to 40%
Benzenes, or naphthenes, or both	40% to 50%
Paraffins	15% to 25%

These figures are very rough, but they are sufficiently reliable to expose the fallacy of attempts to convert heavy crude, or the heavy distillate from our lighter oils, into light products such as gasoline and kerosene. The decomposition by heat, on which all such processes must depend, converts the olefins into very unstable and foul-smelling bodies, while the benzenes and naphthenes are practically unaffected, and only the paraffins are changed to advantage. As the paraffins in the heavy distillates are but a small part of the whole, and as even on these there is considerable loss in the treatment, such methods would be entirely impracticable, even aside from the very high cost of the decomposition itself, and of the subsequent chemical treatment necessary to remove the impurities produced from the olefins. Attempts to convert these heavy oils into marketable light products are based on what appears to be entire ignorance of the principles involved, and are foredoomed to failure.

As an illustration of the small yield of even apparently valuable products, take the case of a sample of distillate from 15° crude oil. This sample was an average of the entire run of distillate from a batch of "D" asphalt, and had the gravity of 25.6° Be. The crude oil would have yielded practically no distillate below 270° C., and whatever is found in the distillate, boiling below this temperature, may be considered as the results of cracking.

This sample, on redistillation, yielded practically nothing below 150° C. (the upper limit for the gasolines) and 37% between 150° and 270°, this distillate having the gravity 35°. On redistilling this fraction for the production of kerosene, the quantity was reduced from 37% to 17% of the bulk distillate. The kerosene thus made was of a dark brown color and had a frightful odor. On treatment with small doses of ordinary sulphuric acid until the odor was removed and a permanent white color obtained, the 17% was reduced to 12%, the difference being absorbed by the acid, while the amount of acid used was about three times the bulk of the white kerosene finally produced. The losses due to conversion of oil into gas during the first distillation amounted to about 2%. In short, the total reduction (loss) in the bulk of oil, in decomposing and chemical treatment, was 7% in producing 12% of kerosene, with an expenditure of acid which alone would amount, at current wholesale rates, to about 45 cents per gallon of kerosene.

Incidental Constituents.—Sulphur and nitrogen are the only bodies found in California petroleum, aside from asphalt, which do not appear to be essential to the make-up of the oil proper. They are found in almost if not quite all of the petroleums of this State.

The percentage of sulphur is usually quite small, and the mode of its occurrence does not seem to have been determined with certainty. From some crude oils it is given off during the early stages of the distillation as sulphuretted hydrogen, or where much water is present, even as free sulphur. The heavier oils usually pass some of the sulphur into the heavier distillates, where it forms some stable combination, which may be redistilled without decomposition. This element is not detrimental to the quality of products, as is the sulphur in some of the Eastern oils, as it is removed very readily during the treatment with sulphuric acid.

Nitrogen is found in most local crude oils, and appears to exist in the form of organic (pyridin ?) bases, soluble in dilute acids.[1] It is readily removed by the acid treatment, and does not appear to have any detrimental effect.

The following table shows the percentages of nitrogen, sulphur, and asphaltene in samples of crude oil from various parts of the State. The sulphur is determined by combustion with sodium peroxid, the nitrogen by Kjeldahl's method, and the asphaltene by precipitation with excess of 70° gasoline, washing and weighing. As the samples on which these determinations were made are not always identical, the gravity of oil used is stated opposite each determination. For other figures on sulphur, reference may be had to the analyses of Mr. H. N. Cooper, in the last table in this bulletin:

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[1] See F. Salathè, 13th Report of the State Mineralogist.

TABLE 28. INCIDENTAL CONSTITUENTS OF CALIFORNIA CRUDE.

DISTRICT.	NITROGEN.		SULPHUR.		ASPHALTENE.	
	Gravity.	Per cent.	Gravity.	Per cent.	Gravity.	Per cent.
Coalinga	34°	0.063	34°	0.068	33°	None.
Coalinga	22	0.302	22	0.817	22	2.04
Coalinga	19	0.314	----	----	19	1.87
Coalinga	18	0.299	18	0.874	18	2.83
Coalinga	16	0.375	----	----	16	2.83
Kern River	15	0.600	14	0.612	15	3.06
Sunset	10	0.370	10	1.253	10	2.93
Sunset	17	0.476	----	----	17	3.01
Midway	20	0.374	----	----	20	1.80
McKittrick	19	0.800	18	0.870	19	2.35
McKittrick	15	0.290	14	0.565	----	----
Santa Maria	17	0.430	----	----	17	8.37
Summerland	----	0.880[1]	15	0.898	15	3.36
Ventura	----	0.606[3]	28	1.500[2]	26	2.05
Los Angeles	----	0.648[4]	14	1.082	14	3.99

It will be seen from these figures that neither sulphur nor nitrogen are present in these oils in such quantity as would interfere with refining operations.

The following table, copied from a paper[5] by Professor Edmund O'Neill, of the University of California, will give an idea of the ultimate constitution of California petroleum:

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[1] S. F. Peckham, Am. Jour. Science, 48-250-255. Mean of 4 samples.

[2] Mabery & Quayle, Jour. Soc. Chem. Ind., 19-502-508.

[3] Mabery & Hudson, Am. Chem. Jour., 25-253. Mean of 13 samples.

[4] Mabery & Hudson, Am. Chem. Jour., 25-253. Mean of 4 samples.

[5] Journal of the American Chemical Society, 25-7, 700.

TABLE 29. ULTIMATE ANALYSES OF CALIFORNIA CRUDE.

District.	Specific Gravity.	Hydrogen.	Carbon.
Colusa	0.9700	10.84%	88.26%
Bakersfield	....	11.30	85.80
Whittier	0.9697	11.50	86.09
Ojai Valley	0.9830	10.81	80.42
Kern	0.9572	12.16	84.86
Bakersfield	0.9572	10.72	86.32
Kern	0.9760	11.18	82.45
McKittrick	0.9458	11.45	86.06
Kern	0.9353	11.30	85.75
Sunset	0.9580	11.30	85.83
Contra Costa	0.9653	10.83	84.66
Coalinga	0.8620	11.80	87.62
Napa County	0.9603	11.13	88.08
Humboldt	0.8810	12.03	86.69
Santa Clara	0.8515	12.88	86.08

Regarding Purification.—The objects and the limitations of the chemical treatment applied to petroleum distillates are so well known that no petroleum refiner needs any suggestions on this subject. But to that portion of the general public which comes into contact with the petroleum business on the refining side, a brief statement may be of interest, particularly in view of the large sums which have been wasted through the attempts of misguided or unscrupulous inventors of "processes."

Petroleum distillates as they come from the still are contaminated in various ways, with nitrogen and sulphur compounds, with asphalt or with the obscure substances which change into that body on exposure to the air, and with the unstable products of decomposition. These are all detrimental to the quality of the oil, in a great number of ways, and the object of the "treatment" is to destroy or remove these substances, leaving the oil a mixture of pure and stable hydrocarbons.

A large number of reagents will destroy or dissolve some of these impurities, but very few will attack all of them, especially when the choice is limited to the commonest and cheapest of chemicals. It has been proven by many years' experience, that to remove the most refractory of the impurities the treating agent must act not only as a solvent, but also as an oxidizing agent, actually burning up and destroying a portion of the impurities. It is probable that every known chemical which can be had at reasonable cost has been used for this purpose, but after numberless experiments refiners have settled on commercial sulphuric acid as being not only much the cheapest, but also by far the best, of all the reagents available. This material is a strong acid, neutralizing bodies of a basic nature, a powerful solvent for the unsaturated hydrocarbons, and one of the strongest oxidizing agents known. Furthermore, it is very heavy, settling readily from the oil, is extremely cheap and everywhere obtainable, and where handled with ordinary discretion is free from any bad effects on the oil.

To remove certain bodies of an acid nature, not acted on by the first treatment, and to free the oil from any traces of the sulphuric acid, an alkaline solution must be used. Almost any alkali would answer this purpose, so long as it is soluble, and the very general use of caustic soda (sodium hydrate) for this purpose is due simply to the fact that, aside from quicklime, which is very difficult to handle, soda is by far the cheapest alkali known, in proportion to its neutralizing strength.

In treating very heavy lubricating oils, any liquid treatment is unsatisfactory, for the reason that it is difficult to settle out the reagents and clear the oil. So that in this field there is undoubtedly room for improvement over the present processes, though there seems very little present prospect of such improvement being made. But so far as the treating of the lighter products from such petroleum as that of California is concerned, it seems very doubtful indeed whether any improvement over the present well-known methods could be made. To be an improvement, the new process must be either cheaper or more effective; effectiveness is a matter of proof in any particular case, and can only be determined by a careful balancing of the results of the new methods against those of the old, taking care that the present methods are applied to the samples under question, by some one familiar with the subject. But when the question of cost is considered, it must be borne in mind that the expense for the chemicals used in purifying the lighter oils is almost infinitesimal, when figured down to a single gallon. The cost of the chemicals used in finishing a gallon of kerosene should not, under any ordinary circumstances, be more than one-third of one cent, while in many cases it is very much less. The claims, sometimes made, of a saving of two or three cents per gallon in the cost of treating kerosene, by the use of some process, are patently absurd.

Another point which should be borne in mind in considering the claims of "process men," is that any chemical treatment has its limitations, which in the nature of things can not be passed. The object of any chemical treatment is to remove impurities, and when these are removed, purification inevitably ceases. If in any particular case the undesirable qualities to be corrected in a distillate are due to impurities, proper treatment will correct these defects, but if they are due to the nature of the oil itself, treatment can not and will not be a remedy. Chemical treatment will never make any notable change in the specific gravity, viscosity, flash point, or boiling point of the lighter products of petroleum, and where defects in burning quality or otherwise are due to these points, or rather to the chemical nature of the oil, thus indicated, no imaginable combination or manipulation of chemicals will have any further effect than would be realized by a simple treatment with the well-known reagents now in use.

The petroleum-refining methods now in vogue are so well settled, by such long experience, that progress is much more likely to be in the way of still manipulation, of reduction of fuel and steam, in prevention of overheating and cracking, in brief, in the adaptation of details and proportions to the particular conditions to be met, than in inventions involving any radical change in the methods of either distillation or chemical treatment.

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CHEMICAL ANALYSES OF

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CALIFORNIA STATE MINING BUREAU

LEWIS E. AUBURY, State Mineralogist.

CHEMICAL ANALYSES OF CALIFORNIA PETROLEUM